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GENERAL

Theoretical and Experimental Methods. 415
Mechanics (Dynamics, Statics, Kinematics)..... 416

MECHANICS OF SOLIDS

Servomechanisms, Governors, Gyroscopics..... 417
Vibrations, Balancing..... 418
Wave Motion in Solids, Impact..... 419
Elasticity Theory..... 419
Experimental Stress Analysis..... 420
Rods, Beams, Cables, Machine Elements. 421
Plates, Disks, Shells, Membranes..... 421
Buckling Problems..... 422
Joints and Joining Methods..... 423
Structures..... 424
Rheology (Plastic, Viscoplastic Flow)... 426
Failure, Mechanics of Solid State..... 427
Material Test Techniques..... 428
Mechanical Properties of Specific Materials..... 428
Mechanics of Forming and Cutting..... 429

MECHANICS OF FLUIDS

Hydraulics; Cavitation; Transport.... 429
Incompressible Flow: Laminar; Viscous. 430
Compressible Flow, Gas Dynamics..... 431
Wave Motion in Fluids..... 434
Turbulence, Boundary Layer, etc..... 434
Aerodynamics of Flight; Wind Forces.. 436
Aeroelasticity (Flutter, Divergence, etc.). 438
Propellers, Fans, Turbines, Pumps, etc... 439
Flow and Flight Test Techniques..... 441

HEAT

Thermodynamics..... 443
Heat and Mass Transfer..... 445
Combustion..... 449

MISCELLANEOUS

Acoustics..... 451
Ballistics, Detonics (Explosions)..... 452
Soil Mechanics, Seepage..... 453
Micromeritics..... 453
Geophysics, Meteorology, Oceanography..... 454
Lubrication: Bearings; Wear..... 454

Letters to the Editor, 455
Books Received, 455

Rarefied Gas Dynamics, S. A. Schaaf, 413

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APPLIED MECHANICS REVIEWS

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RAREFIED GAS DYNAMICS

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1. INTRODUCTION

RAREFIED gas dynamics is concerned with flows at such low density that the molecular mean free path is not negligible. Under these conditions the gas no longer behaves as a continuum. Important modifications in aerodynamic and heat-transfer characteristics occur which are ascribable to the basic molecular structure of the gas.

This branch of gas dynamics has been the subject of many investigations since the time of Maxwell (1). Most of the early studies were related to very low-speed flows, and usually to "internal" geometries—pipes, ducts, orifices and the like—in connection with vacuum problems. The results of this classical research are to be found in the standard kinetic theory texts, e.g., Loeb (2) and Kennard (3). More recently, however, a revival of interest in the field has occurred due to applications to very high-altitude, high-speed flight. A general survey of the field and a definition of significant parameters were presented by Tsien (4), following which a considerable number of experimental and theoretical investigations have been carried out.

It is convenient to subdivide rarefied gas dynamics into three different flow regimes. These are called "free molecule flow," "transition flow," and "slip flow," corresponding, respectively, to extremely rarefied, moderately rarefied, and only slightly rarefied gas flows. This subdivision is desirable because the three flow regimes exhibit quite different phenomena and the basic theoretical approaches are entirely different. Since "rarefied" is a relative term, the demarkation of these three subdivisions is not characterized by absolute pressure or gas density levels, but rather in terms of the ratio of the mean free path λ to some dimension L characteristic of the flow field. The ratio λ/L is called the Knudsen number, K. Free molecule flow corresponds to very large Knudsen number, $K > 10$; slip flow corresponds to Knudsen numbers in the range $0.01 < K < 0.1$; while the transition regime lies in between, with $0.10 < K < 10$. These values are, of course, arbitrary. Phenomena do not change abruptly. However, they seem to correspond pretty well with present experimental evidence.

The mean free path, the sound speed a, and the kinematic viscosity ν are related by $\nu \sim \lambda a$. Hence the Knudsen number is expressible in terms of the two basic parameters of ordinary continuum gas dynamics, namely the Mach number $M = V/a$ and the Reynolds number $Re = VL/\nu$, where V is the reference gas velocity. This relation is $K \sim M/Re$, which is basic for discussion of rarefied gas dynamics.

2. FREE MOLECULE FLOW

This is the extremely rarefied flow regime corresponding generally to flight above 100-miles altitude. The mean free path is many times the characteristic dimension of the flow field—e.g., the diameter of a duct, or the length of a high-altitude rocket. It follows that molecules which impinge on a surface and are then reemitted, travel far away from the surface before colliding with another molecule. For the aerodynamic case the incident flow is thus not disturbed by the presence of the aerodynamic body. For many applications it is valid to assume that the distribution of velocities for the incident molecules is Maxwellian with a superimposed mean velocity with respect to the body. The flux of mass, momentum, and energy incident on a typical surface element of the body may thus be calculated in an unambiguous and straightforward manner.

For the complete determination of aerodynamic and heat-transfer characteristics it is then necessary only to know the distribution of velocities for the reemitted molecules. This, however, is a very difficult matter and, except for molecular beam scattering studies (5), still largely unexplored. There is considerable indirect evidence, however, indicating that for air in contact with typical engineering surfaces such as glass, steel, or aluminum, the reemitted molecules are nearly in Maxwellian equilibrium with the surface at its temperature. Such reemission is called "diffuse" although it clearly implies much more than spatial randomness. It is possible to characterize the actual reemission, not in detail, but rather in terms of over-all average deviations from diffuse reflection. This is done in terms of several "accommodation coefficients" for the transport of momentum and energy. For example, the thermal accommodation coefficient α is defined by

$$\alpha = \frac{E_i - E_r}{E_i - E_w}$$

where E_i and E_r are the actual incident and reemitted energy fluxes, and E_w is the energy flux for the corresponding diffuse case. Similar coefficients σ and σ' are defined for the exchange of tangential and normal momentum. Empirical determinations of these quantities have been made for air (and other gases) and a wide range of surface materials (6,7). The complete prediction of all aerodynamic and heat-transfer characteristics can thus be carried out, and will involve the incident flow, the body temperature, and the three empirical accommodation coefficients.

As is to be expected from the foregoing, the force on a body in general depends on its temperature. At very high speeds, the pressure forces due to the incident flow correspond to the Newtonian approximation of hypersonic theory (8). But the reemitted molecules, as well as the absorption of tangential momentum, have a comparable effect. The over-all force on a body may be as much as twice as high for a surface which is in thermal equilibrium with the incident flow—and thus very hot—as for a body which is at ambient temperature.

One of the most striking results of free-molecule-flow theory is that the equilibrium temperature of any convex body is *higher* than the adiabatic stagnation temperature of the gas flow. This is because, in the absence of intermolecular collisions, many more of the molecules with high velocity relative to the body surface are able to strike it *per unit time* as compared with slower moving molecules, than there are a corresponding number of high-velocity molecules *per unit volume*. The possibility of higher-than-stagnation temperatures for very high altitude vehicles due to this free-molecule-flow phenomenon may be of great importance in some cases.

The calculations based on the theoretical approach just outlined have been carried out for a great number of specific instances and confirmed experimentally over a considerable range of Mach and Knudsen numbers for both heat transfer and forces by Stalder et al., (9,10,11) and others. Theoretical extensions have also been made to the case of very high temperatures for which surface dissociation can occur (12), and to the case of a non-Maxwellian incident flow (13,14). The latter case includes the prediction of a force on a body in the presence of a temperature gradient—even though the gas is macroscopically at rest with no pressure gradient. This is known as the "radiometer" force.

3. SLIP FLOW.

This is the slightly rarefied flow regime corresponding generally to flight at altitudes of 20–50 miles. Here non-continuum effects are just beginning to occur and can be thought of in terms of corrections to continuum relations. In the slip-flow regime, the characteristic dimension of the flow field is often the boundary-layer thickness δ, rather than a length L characteristic of the body itself. Since $\delta/L \sim 1/(Re)^{1/2}$, it follows that the significant Knudsen number, λ/δ, is related to the Mach and Reynolds number by $K = \lambda/\delta \sim M/(Re)^{1/2}$. This relation is customarily used for $Re > 1$, while $K = \lambda/L \sim M/Re$ is used for $Re < 1$.

The slip-flow regime takes its name from the phenomenon of "slip," according to which a gas at low pressures can have a nonvanishing tangential velocity along a solid surface. This is because the molecules next to the surface are composed of roughly half those which originated on the average a distance λ away from the surface (and thus have a finite velocity relative to the surface) and the other half those which are reemitted from the surface (which have average tangential velocity zero for the case of diffuse reflection). A boundary condition results in the form $u \sim \lambda du/dy$, where the factor of proportionality depends on the tangential momentum accommodation coefficient. At normal pressures, $\lambda \sim 0$, so that $u \sim 0$, and the usual continuum no-slip boundary condition obtains. There is a corresponding temperature jump phenomenon described by the relation $T_{gas} - T_{surface} \sim \lambda dT/dy$. These are definite non-continuum phenomena. They are boundary conditions, and they have the effect, by themselves, of reducing skin friction and heat transfer. They have been well confirmed, at least for low-speed flows.

The situation with respect to the basic flow equations themselves is, however, not quite so well established for the slip-flow regime. Until fairly recently it had been thought that some such modification of the Navier-Stokes equations as that formulated by Burnett (15), Grad (16), or Koga (17) would apply. All of these are approximations based on the Maxwell-Boltzmann equation (2,3) of fundamental kinetic theory, which contain the Navier-Stokes equations as a special case for sufficiently small λ. Further theoretical (18,19) and experimental (20,21) work now seems to indicate that none of these "improvements" have general validity, and, in fact, seem actually inferior to the Navier-Stokes equations themselves. Most present theoretical developments in slip flow are thus not being based on the slip and temperature jump boundary conditions, but on the Navier-Stokes equations (including, of course, a non-zero bulk viscosity term for the case of air (22)). The objectives of such theoretical developments are to predict the initial departure from continuum gas dynamic relations. It is not to be expected that results will be applicable to the transition flow regime—much less the free molecule flow regime. It is, in fact, very doubtful if any general theory—apart from the complete Maxwell-Boltzmann equation itself—can be developed for the entire range of conditions covered by rarefied gas dynamics.

From the basic relations $K \sim M/Re$ or $K \sim M/(Re)^{1/2}$, it follows that slip flows are flows of small Re (and consequently large viscous effects), or large M (and consequently large compressibility effects), or both. They are thus also flows in which the so-called "interaction" effects (23) of completely continuum flow are present. Since these effects increase skin friction and heat transfer, it has been very difficult to separate out non-continuum from continuum effects.

A further difficulty has been the fact that the most careful theoretical (24,25,26) and experimental (27,28) work has been carried out for cones and flat plates in supersonic flow, and for these the first-order effect of slip can easily be shown to be zero.

A considerable body of empirical data has been obtained relating to the aerodynamic and heat-transfer characteristics of a variety of geometrical configurations in slip and transition flow (27–37). From these results it seems that, in general, interaction effects are initially more important, but give way to slip and temperature jump effects at lower densities.

4. RESEARCH FACILITIES

The development of supersonic wind tunnels, molecular beams, and other research facilities for exploring the rarefied gas dynamics field has posed many new problems. Three such wind tunnels are now in operation—at Ames Laboratory of NACA, at Berkeley, and at Toronto. All use once-through-type tunnels, driven by large vacuum pumping units, which expand air from a stagnation pressure of the order of a few mm Hg to the order of 0.05–0.50 mm Hg at the test section. The convergent-divergent nozzles to produce the supersonic flow are axially symmetric so as to enable a uniform correction for the thick boundary layers occurring at the low Reynolds numbers of the tests. Impact and static pressure probes have large response times—particularly when they are small—and also must be corrected for viscous effects. Impact pressures, for example, are usually higher than the ideal values given by the Rayleigh formula.

Several new types of instruments have had to be developed. Wind-tunnel test-section densities are too low to enable index-of-refraction techniques of flow visualization, such as schlieren, shadowgraph, or interferometer, to be workable. However, the emissive and absorptive characteristics of air and other gases have been successfully utilized to obtain photographic data depicting shock waves, boundary layers, wakes, and the like. Air, nitrogen, argon, helium, and other test gases can be electrically excited into a light-emitting "afterglow" state permitting direct observation and photography of the low-density flow fields. The absorption of ultra-violet light by oxygen permits another type of photographic record of the density variations. A similar technique based on the scattering of an electron beam is also being developed. Another new wind-tunnel instrument, known as the "free molecule probe,"

has also been developed. The dependence in free molecule flow of equilibrium body temperature to local Mach number, noted above, forms the basis of this instrument. A very small wire, with diameter less than the mean free path, is stretched across the test section and used as a thermometer, giving a good indication of the Mach number variation as it is traversed. Such an instrument was used by Sherman (20) in probing the detailed structure of a shock wave.

5. CURRENT AND FUTURE PROBLEMS

Considerable effort is being made to extend the range of empirical data—particularly in the slip and transition flow regimes.

A very great advance will be made when the theoretical and experimental separation of slip flow and interaction phenomenon has been achieved.

More needs to be known about the flow field in the immediate vicinity of the leading edge of very sharp bodies. Does the incident flow strike the body almost undisturbed and slip along the surface for a few mean free paths, or does the boundary layer pile up the fluid ahead of even a sharp leading edge so that the flow is quite slow when it finally reaches the surface? For very high Mach numbers these two extremes can have very widely different results far downstream from the leading edge region itself.

Most rarefied gas dynamics research has been confined to relatively low temperatures. In the next few years it will be necessary to extend both experimental and theoretical considerations to very high temperatures, both with respect to molecule-surface interaction and to dissociation and other effects in the gas flow. Since there are fewer intermolecular collisions in a low-density gas flow than in a corresponding high-density flow, the effects of lags in the adjustment to thermodynamic equilibrium become much more important. It is also to be expected that high-altitude applications will require knowledge of the aerodynamic characteristics of partially ionized gases. Such considerations open up a whole new area of theoretical and experimental problems.

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"Letters to the Editor" and "Books Received for Review" now appear after the reviews

Theoretical and Experimental Methods

(See also Revs. 3173, 3174, 3176, 3177, 3179, 3186, 3195, 3198, 3223, 3227, 3265, 3268, 3275, 3280, 3313, 3378, 3383, 3386, 3430, 3432, 3451, 3458)

3152. Vernotte, P., Scientific applications of the notion of regularity (in French), *Publ. sci. tech. Min. Air, France* no. 307, 84 pp., 1956.

Author defines the regularity of a given sequence of equidistant abscissas by conditions of the sign in a table of successive differences.

These conditions are so concise that one may solve the problem of interpolation and related problems simply by expressing corresponding linear inequalities; and moreover, with a close approximation which is obtained very quickly and which is correct in the limit. For justification one may study the example of the interpolation of factorials because the knowledge that one has of the Gamma function allows one an assured control of the results.

The same principle is applied to the errors of physical measure-

ments in a form which is not much different, the rough measurements being corrected, within the limits of precision which have been anticipated, by retouching the table of successive differences in such a way that it satisfies the so-called sign condition.

From author's summary by A. Devinatz, USA

3153. Aruffo, G., On the conditions of validity of the general Green-Stokes theorem (in Italian), *Acta Pont. Acad. Sci.* **15**, 1, 1–14, 1951.

Author proves the validity of the Green-Stokes theorem in Euclidean space of arbitrary dimension if the conditions of differentiability are weakened in a sense similar to those given by Goursat in the case of the Cauchy integral theorem. It is stated that this integral theorem can be deduced, under these conditions, from the Green-Stokes theorem.

A. van Heemert, Holland

3154. Aitken, A. C., Studies in practical mathematics. VIII. On the iterative methods of Lin and Friedman for factorizing polynomials, *Proc. roy. Soc. Edinburgh* (A) **64**, part II, 190–199, 1955.

The problem treated here is the numerical computation of coefficients of a low-order polynomial which is a factor of a given polynomial of higher order; this problem is encountered in solving algebraic equations having multiple roots or sets of roots with almost equal moduli. A method of S. N. Lin [*J. Math. Phys.* **20**, 231–241, 1941] had previously been discussed by the author [*Proc. roy. Soc. Edin.* (A) **63**, 174–191, 1952], who investigated its rate of convergence and suggested an acceleration procedure. In the present paper, the same kind of discussion is applied to two more recent methods, one given by Lin [*J. Math. Phys.* **21**, 60–77, 1943], the other by B. Friedman [AMR **4**, Rev. 30]. Both are iterative methods involving repeated division of the given polynomial by trial factors. The errors after the n-th approximation are related to those after the $(n-1)$ st by a matrix which the author determines explicitly. The leading characteristic root of this matrix determines whether and how rapidly the iterations converge in any given case. Author conjectures that both methods are less desirable than Lin's older method. This conjecture is partly based on his inability to find accelerative procedures similar to the one he devised for the earlier method, and also on his inability to apply some of the same elegant theoretical simplifications. In one numerical example given, Lin's second method converges more slowly than either of the other two, Friedman's more rapidly than either, though at the cost of somewhat more computing work. Lin's first method modified by Aitken's acceleration device would apparently be best.

F. L. Alt, USA

3155. Pode, L., and Rosenthal, L., Cable function tables for small critical angles, *David W. Taylor Mod. Basin Suppl. Rep.* 687, 105 pp, Sept. 1955.

Supplementary tables of the cable functions used for determining the shape and tension of a flexible cable immersed in a uniform stream are presented. The tables cover the range of critical angles from 0 to 10 degrees in increments of one degree. In the neighborhood of the critical angle, values of the functions are given at intervals of 0.5 degree.

From authors' summary

3156. Wildhaber, E., Surface curvature, *Prod. Engng.* **27**, 5, 184–191, May 1956.

A useful method is given for defining and generating warped surfaces, such as embodied in helical gears, worm threads, and hypoid gears. Physical significance of curvature and derivation of concepts and equations is reviewed. Two sample applications demonstrate the method.

From author's summary

Book—3157. Fieller, E. C., Lewis, T., and Pearson, E. S., Correlated random normal deviates (Tracts for computers, No. XXVI), Cambridge, University Press, 1955, xv + 60 pp. 10s/6d.

These tables give in effect 3000 random pairs from each of 9 bivariate normal distributions with respective correlation coefficients 0.1(0.1)0.9. Tables are based on items in work of H. Wold ["Random normal deviates," Tracts for computers, No. 25, Cambridge University Press, 1948].

Y. L. Luke, USA

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Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 3371, 3441, 3442, 3443, 3463)

3166. Muttnyánszky, Á., Discussion on "Determination of critical speed of the first order of Sharpless supercentrifuges equipped with vertical axis" by István Thamm (in Hungarian), Gép **7**, 8, 314–319, Aug. 1955.

Author examines critical speed of the second order caused by a gyroscopical effect on flexible shafts with elastic bearings loaded with a long solid rotor in the middle of the span. In addition to the known relation $\omega^2_{cr1} = 1/(cm)$ caused by the eccentricity, he concludes the relation $\omega^2_{cr2} = 1/[c_0(\theta_1 - \theta_3)]$ caused by the keying on bias of the rotor. The $1/c = k$ is the linear stiffness, $1/c_0 = k_0$ is the angular stiffness defined as the moment necessary to produce a unit angular displacement at the plane of the rotor, θ_1 is the moment of inertia of the rotor about one of its diameters through its gravity center, and θ_3 is the same about shaft axis.

S. Dunkerley appears to have been the first to establish the critical speed of this kind for the case of an overhung shaft loaded with a thin disk on the free end by the form $\omega^2_{cr} = 12gIE/(Wl^3)$, W being the weight of the disk, l being the length of the shaft ["On the whirling and vibration of shafts," *Phil. Trans. roy. Soc., Lond.* (A) **185**, part I, p. 279, 1895]. Later M. Herrmann gives for the same case a formula $\omega^2_{cr} = 2lE/\theta_3 l)$ which is based on the same ground as that of Muttnyánszky ["Machine elements (Gepelemek)," (in Hungarian), Budapest, Nemeth, 1924]. Concerning a shaft on two supports with a thin disk in the middle of the span, Timoshenko establishes the formula $\omega^2_{cr} = k_0/(\theta_1 + \theta_3)$ ["Vibration problems in engineering," New York, Van Nostrand, 1928]. But effec-

tive critical speeds given by the later authors do not take place in contrast (or contradiction) to Muttnyánszky.

Author asserts that the reason he did not publish his original article a few years ago is that the work of C. Weber, "Vibrations in mechanical engineering, (Schwingungen im Maschinenbau)," Düsseldorf, Deutscher Ing.-Verlag, 1953, appeared in the meantime giving the value of ω_{cr2}.

Author examines further the rate of $\omega_{cr2}/\omega_{cr1}$ in the case of a unit centrifugal force and a unit gyroscopic moment at different rotor proportions.

Next he examines the critical speed of the Sharpless supercentrifuge caused by the centrifugal force in common with the gyroscopic moment, with the aid of the formula of Dunkerley and Stodola which is valid also for rotors with a load off center. Here the real rotor is replaced by a simplified system which can be formed to a very simple swinging system, that is, a weightless cantilever beam with a swinging mass on the free end.

Author's merit is that he calls attention to the fact that the working angular displacement has importance in the gyroscopical moment and not when in a state of rest.

The examination of $\omega_{cr2}/\omega_{cr1}$ demonstrates well the influence of the alteration of the rotor shape on the critical speed. The system substituting the Sharpless supercentrifuge is ingenious; the solution is clear cut.

The detailed and systematic treatment of the subject gives a clear idea of the complicated relations. The exceedingly perspicuous demonstration of the physical background assures the possibility of adopting a smaller mathematical apparatus.

G. Pattantyus, Hungary

3167. Boenke, G., Kinematic investigation of a valve mechanism having pivoted follower (in German), *Maschinenbau-Technik* **5,** 3, 140-143, Mar. 1956.

A thorough analysis is made of a valve mechanism of the overhead-valve type wherein the cam follower is pivoted and the rod between the follower and the rocker consequently oscillates rather than reciprocates. It is shown that this mechanical arrangement requires much greater spring forces in order to maintain satisfactory contact between the various members of the linkage under operating conditions. C. E. Balleisen, USA

3168. Nerge, G., Linkage adjustment and its application (in German), *Maschinenbau-Technik* **5,** 3, p. 133, Mar. 1956.

A short and routine paper showing how to proportion a four-bar mechanism to meet given displacement requirements.

C. E. Balleisen, USA

3169. Rössner, W., Determination of the Burmester points in singular cases and in application of linkage syntheses (in German), *Maschinenbau-Technik* **4,** 5, 238-260, June 1955.

For the kinetic synthesis, the exceptional cases of Burmester center-point and circle-point diagrams are used in order to avoid the point-by-point investigation in such diagrams of general shape. This was favored especially by Lichtenheldt's ascertaining how and in which areas of three arbitrary positions the fourth may be supposed to lie, for a determined disintegration of the center-point diagram. He indicated a simple method of construction for this very frequent task of kinetic synthesis.

Using this method, construction will become far more economical. The present study investigates the relations in the case where, in addition to the four positions of a plane—which would lead to an exceptional case of the center-point diagram—a fifth position is arbitrarily assumed for the purpose of defining still more exactly a certain law of motion. When five positions of plane are given,—as a rule only the mutual sections of five different center-point diagrams—the so-called Burmester points may be used as geometric positions for the kinetic construction. By special arrangement of four plane positions, one of the possible fifth center-point diagrams may disintegrate into more simple components. In this case, the finding of the Burmester points would require the tracing of at least one more of the four other center-point diagrams of general shape.

It is shown how to simplify, in such a case, the finding of the Burmester points, i.e., besides disintegration components of the one center-point diagram, we need only trace the straight lines, circles, or conic sections. This depends on the results of the square relationship or other geometric relations. Some examples demonstrate the method in practice.

From author's summary by J. N. Aguirre, Argentina

3170. Inomata, S., Study on torque meter, *J. mech. Lab. Tokyo* **1,** 2, p. 50, 1955.

3171. Kurz, P. F., Useful friction recorder, *Amer. J. Phys.* **24,** 3, 174-175, Mar. 1956.

A simple apparatus for recording frictional forces and changes in such forces encountered in traversing plane surfaces is described. Typical records are presented, and the flexibility of the apparatus is discussed. From author's summary

3172. Peterson, M. B., and Johnson, R. L., Friction studies of graphite and mixtures of graphite with several metallic oxides and salts at temperatures to 1000° F, *NACA TN* 3657, 16 pp., Feb. 1956.

An experimental friction study was made using graphite and mixtures of graphite with lead oxide, cadmium oxide, sodium sulfate, or cadmium sulfate as solid lubricants. Runs were made at temperatures up to 1000F with various steel and Inconel combinations.

Graphite powder lubricated metal surfaces at temperatures sufficiently high to promote oxidation of the metal surfaces. At intermediate temperatures, graphite powder alone failed to function as a lubricant. Graphite would not lubricate cast Inconel on Inconel X at temperatures between approximately 150 and 800F. Similarly, with steel, which oxidized more readily than Inconel, the temperature below which graphite would not lubricate was 475F as compared with 800F for Inconel.

Mixtures of metallic compounds and graphite were effective lubricants from room temperature to 1000F provided no reaction occurred between the metallic compounds and the graphite. A metallic salt mixed with graphite showed friction coefficients similar to those of a resin-bonded film of graphite.

From authors' summary

Servomechanisms, Governors, Gyroscopics

(See also Revs. 3262, 3263, 3264, 3266, 3273, 3299, 3327, 3328, 3368, 3408)

3173. Bendrikov, G. A., and Teodorchik, K. F., Laws of the root migration of linear algebraic equations of the third and fourth order applied to conditions of continuous fluctuation of the free term (in Russian), *Avtomatika i Telemekhanika* **16,** 3, 288-292, 1955.

Authors investigate the general n-th order characteristic equation applicable in automatic control theory. The qualitative analysis is applied to third- and fourth-order equations, and regions of maximum stability are given. Included are two tables indicating the behavior of the characteristic equations as the free term varies. M. D. Friedman, USA

3174. Andre, J., and Seibert, P., On piecewise linear differential equations occurring in automatic control problems (in German), *Arch. Math.* **7,** 2, 148-156, 1956.

3175. Coales, J. F., Nonlinearity in control systems: An informal appraisal of the problem, *Control Engng.* **3,** 2, 55–56, Feb. 1956.

3176. Gibson, J. E., A dynamic root-locus plotter, *Control Engng.* **3,** 2, 63–65, Feb. 1956.

3177. Burian, K., and McMaster, S., How to determine impedance components graphically, *Control Engng.* **3,** 2, p. 66, Feb. 1956.

3178. Sissingh, G. J., The frequency response of the ordinary rotor blade, the Hiller servo-blade, and the Young-Bell stabiliser, *Aero. Res. Counc. Lond. Rep. Mem.* 2860, 19 pp., 1954.

The present report deals with the frequency response of pivoted gyratory systems and, in particular, with the response of the ordinary rotor blade, the Hiller servo-blade, and the Young-Bell stabilizer to sinusoidal disturbances caused by pitching oscillations with constant amplitude. Physically, the problem corresponds to a single-degree-of-freedom system excited by beats. The resulting forced oscillations are characterized by the two following phase angles: (*a*) a phase angle in the plane of rotation; (*b*) a phase angle of the oscillation of the tip-path plane, where the tip-path plane may be considered as a solid body. The latter, which is the controlling consideration, depends on the specific damping of the system and the frequency ratio.

In general, the tip-path plane of the systems mentioned oscillates in two directions, longitudinal and lateral, where both modes of oscillation can be split up into components in phase with the attitude and in phase with the rate of change of attitude. For each individual system explicit formulas are given, and the effect of the frequency ratio on the control characteristics of the Bell stabilizer and the Hiller servo-blade is shown by vector loci.

From author's summary

Vibrations, Balancing

(See also Revs. 3187, 3214, 3228, 3229, 3261, 3428, 3433, 3451)

3179. Marguerre, K., Vibration and stability problems of beams treated by matrices, *J. Math. Phys.* **35,** 1, 28–43, Apr. 1956.

Both the method of influence coefficients and that of Myklestad used in the solution of vibration problems involve matrix calculus. The matrix method applied to the differential equation of a vibrating beam and of a buckling column is reviewed. It is also shown that matrixes can be very useful in calculating exact eigenvalues of vibrating and buckling beams with varying cross section and intermediate supports. It is further shown how these calculations can be shortened as well as made more accurate by the use of auxiliary matrixes, called delta-matrixes. Finally, a list of matrixes suitable for these calculations is given.

J. P. Vidosic, USA

3180. Miles, J. W., Vibrations of beams on many supports, *Proc. Amer. Soc. civ. Engrs.* **82,** EM I (*J. Engng. Mech. Div.*), Pap. 863, 9, pp., Jan. 1956.

The natural frequencies of a continuous beam resting on an arbitrary number of uniformly spaced supports are determined from a difference equation formulation. These frequencies fall in periodically spaced groups that are separated by spectral gaps of widths equal to approximately half the interval between the natural frequencies of a single beam on a square root frequency scale. These groups tend to uniform spectra as the number of supports to infinity, but the gaps remain, giving a band-pass character to the entire spectrum. Wave propagation along an infinite, periodically supported beam is discussed and the phase and group velocities evaluated as functions of frequency.

From author's summary by R. Giovannozzi, Italy

3181. Weidenhammer, F., Stability of nonlinear bending vibrations of beams with pulsating axial loads (in German), *Ing.-Arch.* **24,** 1, 53–68, 1956.

Under pulsating axial loads, a beam may execute bending vibrations of finite amplitude, if the exciting frequency is about twice one of the natural bending frequencies ($\omega \approx 2\,\omega_j$). These nonlinear oscillations are studied for a simply supported beam. The transient vibrations, particularly, are examined, by the "method of slowly varying phase and amplitude" (van der Pol), in order to determine the manner in which the steady-state vibration depends on the initial lateral disturbance. It is shown that, for forcing frequencies of $\omega > \omega_j$, the beam may return to rest or it may reach steady finite-amplitude oscillations. Paper also considers the effect of damping and shows the corresponding resonance curve to be everywhere finite. The results are derived by an approximation method and their general validity is demonstrated by use of a method due to J. Haag.

From author's summary by G. A. Nothmann, USA

3182. Adler, A. A., Bending and torsional vibrations of nonuniform beams, Thesis, M. Sc. Mech. Engng., Graduate School, Cornell Univ., 51 pp., Sept. 1955.

Using an inverse method author is able to develop a classification relating beam parameters to the corresponding solutions of the governing differential equations. Only beams with rectangular or elliptical cross sections having depth and width as simple monomial functions of the length variable are considered.

J. L. Bogdanoff, USA

3183. Yeh, G. C. K., and Martinek, J., Forced vibration of a clamped rectangular plate in fluid media, *J. appl. Mech.* **22,** 4, 568–572, Dec. 1955.

The plate is clamped in a rigid infinite baffle which separates two different fluid media, and is excited by a plane wave normally incident from one side. The wave lengths in both media are assumed to be of small order compared with the edge lengths of the plate. The deflection of the plate is expressed in a double series, and Ritz method is used in shape of Lagrange calculus. Numerical results about the energy transmission are presented based on a four-term series. H. Schaefer, Germany

3184. Baron, M. L., Circular-symmetric vibrations of infinitely long cylindrical shells with equidistant stiffeners, *J. appl. Mech.* **32,** 2, 316–318 (Brief Notes), June 1956.

Tables for the determination of frequencies of the modes specified in title are presented. It is assumed that the spacing of stiffening rings is small compared with the radius of cross section, so that motion of shell parallel to axis of cylinder may be neglected. Only oscillations having same periodicity as stiffener spacing are considered. Allowance has been made in the analysis for additional mass, uniformly distributed over shell, which offers no resistance to deformation; for instance, insulation.

The note is an extract of Tech. Report 11, Office of Naval Research Contract Nonr 266(08), AFSWP 871, Columbia University, 1954, having same title and author.

From author's summary by M. J. P. Musgrave, England

3185. Lakshmana Rao, S. K., On the vibrations of triangular membranes, *J. Indian Inst. Sci.* (*A & B*) **38,** 1, 1–3, Jan. 1956.

Paper reviews the solutions of the differential equation governing the propagation of waves in thin membranes for the classic problems of regions comprising a right-angled isoceles triangle, and a right-angled 30° –60° triangle. Solutions can be extended

to equilateral triangle, rhombus with acute angle of 60°, and regular hexagon regions. J. B. Duke, USA

3186. **Holzweissig, F., Limit methods for the determination of eigenfrequencies** (in German), *Maschinenbau-Technik* **5**, 4, 195–200, Apr. 1956.

In order to determine the eigenfrequencies of vibrations of systems with several degrees of freedom, certain assumptions must be made. Corresponding to different methods, the fundamental frequency, the position of nodes, or similar data are assumed. The present work determines a domain in which the fundamental frequency and a lower bound of the first harmonic can lie. With the aid of useful coefficients, a scheme for the calculation of exact values of the frequencies can be developed. For a torsional vibration system with n masses, two different tabular methods for the determination of these coefficients are constructed.

From author's summary by W. H. Hoppmann II, USA

Wave Motion in Solids, Impact

(See also Revs. 3180, 3251, 3452)

3187. **Dengler, M. A., Transverse waves in beams and plates under impact loading** (in German), *Öst. Ing.-Arch.* **10**, 1, 39–66, 1956.

Paper presents results already given in AMR **6**, Rev. 2703 and AMR **8**, Rev. 1588, with the addition of intermediate mathematical details and a brief analysis of transverse impact on plates.

H. N. Abramson, USA

3188. **Adamson, B., Behaviour of elastic beams under action of detonating charges with special reference to rotatory inertia and shearing forces,** (in Swedish), *Kungl. Fortifikationsforvaltningen Befastningsbyran Rap.* **109**: 10, 130 pp., 1955.

Report describes an experimental and theoretical investigation into the vibrations produced in elastic beams under the impulse loading produced by explosions. A review of the one-dimensional theories of bending is given, including the effects of rotatory inertia. The problem is also considered in three dimensions and a comparison is made with one-dimensional theory. Solutions are given in the case of an impulse load decaying exponentially with the time and with the boundary conditions used in the experiments, viz., vertical motion prevented, horizontal motion allowed, and bending moment zero. The beam was set in motion so as to excite the odd normal modes (up to the eleventh) in turn, and the damping coefficients were measured and the normal frequencies were compared with theory. Timoshenko's theory gave the best fit. Observed strain-time curves were compared with those calculated from theory. Again the best general agreement was obtained with Timoshenko's theory both as regards form and magnitude. Author concludes with an extensive bibliography.

J. M. Jackson, Scotland

3189. **Bogdanoff, J. L., Influence of secondary inertia terms on natural frequencies of rotating beams,** *J. appl. Mech.* **22**, 4, 587–591, Dec. 1955.

The equations of small motion of a straight cantilever beam attached to the rim of a rotating disk are determined assuming the Bernoulli-Euler theory of bending and the Saint-Venant theory of torsion are valid, the mass and elastic axes coinciding and retaining all inertia terms. Influence of the secondary inertia terms on the fundamental torsional and lateral frequencies is then examined at two angular settings for a uniform beam having a length of disk-radius ratio in the range usually encountered in gas-turbine buckets and axial-flow compressor blades.

From author's summary by G. Temple, England

3190. **Biot, M. A., Theory of propagation of elastic waves in a fluid-saturated porous solid, I. Low frequency range,** *J. acoust. Soc. Amer.* **28**, 2, 168–178, Mar. 1956.

Paper develops clearly and in considerable detail a theory assuming statistically isotropic solid, compressible fluid, and comparable densities for fluid and solid. Frictionless fluid is considered first, then Poisseuille flow in pores. Theory applies only for frequencies below critical frequency at which assumption of Poisseuille flow breaks down.

Stress-strain relations for the solid-fluid system and dynamic relations between stresses and accelerators are set up and combined to show there are two dilatational waves, one of which attenuates rapidly and one of which may or may not attenuate rapidly, depending on the relative motions between solid and fluid. In addition, there is an uncoupled rotational wave of attenuation proportional to frequency squared. Curves are given relating phase velocities and attenuation to nondimensional parameter proportional to frequency. K. M. Siegel, USA

3191. **Biot, M. A., Theory of propagation of elastic waves in a fluid-saturated porous solid. II. Higher frequency range,** *J. acoust. Soc. Amer.* **28**, 2, 179–191, Mar. 1956.

Theory of part I is extended to frequency range between previous critical frequency and frequency at which the pore dimensions are of the order of a wave length. Theory takes into account variation of viscosity with frequency, including approximate effect of pore cross-sectional size and shape under assumption of uniform pore-size and shape distribution. Curves relate phase and group velocities, attenuation and attenuation per cycle to frequency for various combinations of parameters. K. M. Siegel, USA

Elasticity Theory

(See also Revs. 3200, 3205, 3206, 3207, 3216, 3222, 3239, 3242, 3249, 3351, 3377)

3192. **Geckler, R. D., Thermal stresses in solid propellant grains,** *Jet Propulsion* **26**, 2, 93–97, Feb. 1956.

The problem of determining the transient thermal stresses in a hollow circular cylinder is an extension of a previous paper [*Jet Propulsion* **25**, 1, 30–35, Jan. 1955]. The problem solved is that of a hollow cylinder, insulated at its inner surface at an initially uniform temperature, whose outer surface is suddenly placed in an environment whose temperature is different from the initial temperature of the cylinder. The solution includes the effect of a film coefficient at the outer surface but considers this heat-transfer coefficient independent of temperature. The first part of the paper is based on the thermal stress solution given by Timoshenko [AMR **5**, Rev. 43] in which the modulus of elasticity and thermal coefficient of expansion are considered to be independent of temperature. The solution for the temperature-distribution problem is based on analysis by Jaeger [*Phil. Mag.* **7**, 36, 418-428, 1945], in which the solution is expressed as a series of Bessel functions of the first and second kind and requires an evaluation of the roots of a transcendental equation involving these Bessel functions. The calculation of these roots is, in itself, a formidable undertaking and is to be published by M. Lipow and S. A. Swick in the *J. Math. Phys.* Using the cited calculated roots, the author, in his previous paper, determines the temperature distribution; in this paper, he has presented the stresses caused by these thermal gardients in a concise graphical form.

The problem considered here is that for which the resultant of the longitudinal stresses is zero, i.e., there is no restraint to axial elongation, and in which the end effect problem for short cylinders is neglected.

The second part of the paper extends the solution obtained in the first part to include the effect of the dependence of the modulus of elasticity on temperature. An iterative-type procedure beginning with the solution already obtained and using the equations obtained by H. Hilton [AMR **6**, Rev. 770] is used to include this effect. A. L. Ross, USA

Book—3193. Thompson, A. S., and Rodger, O. E., Thermal power from nuclear reactors, New York, John Wiley & Sons, Inc., 1956, xiii + 229 pp. $7.25.

This is the latest book to appear which claims to cover the engineering aspects of nuclear reactors. Authors attempt to cover this very broad subject in a relatively short book of only 223 pages. In the first 158 pages, the nuclear aspects of the subject are treated from an elementary point of view, including a discussion of the application of dimensional analysis to reactor design and non linear reactor kinetic. Chapter headings are (1) Nuclear considerations; (2) Reactor equations and critical mass; (3) Reactor kinetics; (4) Shielding of reactors, 16 pages; (5) Reactor materials, 12 pages. In the remaining 66 pages of the book—the topic of which is power removal from reactors—the authors attempt to discuss the many aspects of the mechanical and thermal design of reactors. For example, in 20 pages, pressure losses in fluid flow, heat transfer to flowing fluids, boiling heat transfer, heat-transfer analogies, and power density and pumping efficiencies are mentioned. Similarly in 17 pages, thermal power cycles and, in 26 pages, thermal stresses are discussed.

There is a decided lack of applications to design problems and particularly a lack of descriptions of current designs to go with this brief discussion of engineering design of reactors. The book can only be considered as an extremely brief introduction to the field of reactor design. R. S. Wick, USA

3194. Volterra, E., On the deflections of bow girders of noncircular shapes, *Proc. Amer. Soc. civ. Engrs.* **82,** EM 1 (*J. Engng. Mech. Div.*), Pap. 870, 12 pp. + 13 figs., Jan. 1956.

When the central line of arc bow girders is circular, principle of minimum strain energy is generally used to solve statically indeterminate problems, but in the case of noncircular shapes the resulting expressions ought to be calculated approximately by numerical methods. Author uses instead the two differential equations which relate displacements (transverse deflection and rotation about the axis) to external loads and which are derived from Saint-Venant's equations of the deflection curve combined with equilibrium equations referring moments to load.

By means of well-suited developments these equations are integrated in closed form for different shapes (cycloid, catenary, parabola), the load being uniformly distributed; problem is solved by satisfaction of boundary conditions at built-in ends.

Graphs of deflection and rotation, of bending and twisting moments are obtained for different angular amplitudes of beam and different ratios between flexural and torsional rigidity.

D. Gentiloni-Silverj, Italy

3195. Rivlin, R. S., Stress-relaxation in incompressible elastic materials at constant deformation, *Quart. appl. Math.* **14,** 1, 83–89, Apr. 1956.

For an ideally incompressible elastic material capable of stress-relaxing, author shows that the stress components at a point of a body may be expressed as polynomials in the gradients of displacements with time-dependent coefficients. The relationship between these time-dependent coefficients and strain energy is discussed by comparing the theory of finite elastic deformations with the present theory for the case of time $t = 0$. Thus it is shown that the stress relaxation in incompressible elastic bodies may be solved by employing the aforementioned relationship. By using this approach, results are found for cases of: (1) simple tension; (2) simultaneous simple extension and torsion of a circular rod or tube; and (3) small torsion superimposed on simple extension of a uniform rod of arbitrary cross section. L.-W. Hu, USA

3196. Braun, O., Examples of simplified computation of the loading terms in the elasticity equations, *J. Boston Soc. civ. Engrs.* **43,** 2, 128–141, Apr. 1956.

3197. Rongved, L., Force at point in the interior of a semi-infinite solid with fixed boundary, *J. appl. Mech.* **22,** 4, 545–546, Dec. 1955.

Solution of the title problem is obtained in closed form by an application of potential theory, using the Boussinesq-Papkovitch functions and Green's function for Poisson's equation and the half space. The case of the force parallel to the boundary, as well as that of the force perpendicular to the boundary, is treated.

R. D. Mindlin, USA

3198. Camiz, V., Graphical composition of plane states of stress (in Italian), *Ingegnere* **29,** 7, 731-742, July 1955.

After recalling the fundamental properties of Mohr's circle, paper shows some simple graphical methods which allow to obtain, from the circles associated with two or more plane states of stress acting on the same plane, the circle associated with the resultant state of stress. In considering the inverse problem, in particular the case in which the component states are required to be uniaxial, author shows that the solution is not unique and analyzes the possibility of arbitrarily establishing the directions of the component states of stress.

From author's summary by E. Saleme, USA

3199. Netrebko, V. P., Torsion of an elastic parallelepiped with a given law of distribution of the shearing stress on the bases (in Russian), *Vestnik Moskov. Univ.* **9,** 12, 15–26, 1954.

An approximate solution of the torsion problem for an elastic rectangular parallelepiped with specified distribution of shearing stresses on the bases is obtained by minimizing the potential energy of deformation. A numerical example suggests that the stress distribution does not deviate materially from Saint-Venant's distribution in cross sections whose distance from the loaded ends exceeds the greatest linear dimension of the ends.

I. S. Sokolnikoff, USA

Experimental Stress Analysis

(See also Revs. 3179, 3223, 3232, 3255, 3258)

3200. Christodoulides, S. P., A photoelastic method of two-dimensional separation of stresses along a line of symmetry by using the isochromatic fringes only, *Brit. J. appl. Phys.* **7,** 5, 190–194, May 1956.

Paper begins with Stevenson's equation for stresses, including body forces as expressed in complex notation. Author transforms this from x,y axes to a set of orthogonal curvilinear axes, n, s, which are the principal stress trajectories. The resulting equations are of the Lame-Maxwell form, when the case of no body forces is considered. By setting up the equations in terms of principal stresses, and considering the special case where there is at least one axis of symmetry, author shows that (1) at any point on the line of symmetry, the principal stress trajectory and the curve orthogonal to the isoclinic at that point both have the same curvature, and (2) at any point on a line of symmetry, the principal stress trajectory and the isochromatic at that point both have the same curvature.

Since the isochromatics are obtainable directly by photographic means, the Lame-Maxwell equations are derived in terms of them and their curvature. This permits the separation of the principal

stresses. A convenient method is shown for measuring the curvature. Simpson's rule is used to perform the integrations in a worked-out example of a circular hole in a tension bar.

T. A. Hunter, USA

Rods, Beams, Cables, Machine Elements

(See also Revs. 3156, 3179, 3180, 3181, 3182, 3194)

3201. Mink, K., Design of composite beams (in German), *Bauingenieur* **31**, 5, 172-174, May 1956.

Plane of bending moment is symmetry plane of the beam. There is no other symmetry. A set of elementary formulas is deduced which makes it possible to compute necessary flange areas by given bending moment, maximum tensile and maximum compressive stress. Numerical example is worked out.

W. L. Esmeijer, Holland

3202. Oravas, G., Calculation of circular beams on elastic foundation (in German), *Bauingenieur* **31**, 5, 177-180, May 1956.

The problems solved by E. Volterra [AMR **5**, Rev. 1327; **7**, Rev. 49] on the bending of circular beams on elastic foundation are extended to include concentrated moments acting on the beam, as well as to take into consideration the torsional stiffness of the foundation. Governing differential equations remain of the same form as when the latter is not considered; the solution is therefore trivial. Paper would serve the needs of engineering better if numerical examples were included showing the effect of the torsional stiffness.

Y.-Y. Yu, USA

3203. Worch, G., Analysis of continuous beams on multiple elastic supports (in German), *Bauingenieur* **30**, 11, 388-392, Nov. 1955.

Paper gives an alternative reading of a method, given by Koiter and inserted in Biezeno-Grammel, 2nd ed., vol. 1, p. 268, Berlin 1953.

J. F. Besseling, Holland

3204. Zaytzeff, S., Calculation of beams on elastic foundations. Parts 1, 2 (in French), *Tech. mod. Constr.* **11**, 3, 85-92, Mar. 1956; **11**, 4, 121-126, Apr. 1956.

Utilizing the conventional Winkler assumption that the reaction forces of the foundation are proportional at every point to the deflection of the beam at that point, author reviews the fundamental theory and discusses the known solutions for some practical cases. Most of the solutions presented are available in Hetenyi, "Beams on elastic foundations," or other texts. However, author presents the results in a form that may be more convenient for the use of designers.

N. M. Newmark, USA

3205. Harboe, H., Circular beam, simple span with ends supported and fixed as to slope but not as to roll, subjected to a concentrated load acting perpendicular to plane of curvature, *Bygnstat. Medd.* **27**, 1, 1-7, Feb. 1956.

For the system and loading condition mentioned in title, simple approximative formulas are given, without demonstration, for redundant reaction (bending moment) in the one end of the curved beam. There will be a considerable reduction of work in thus calculating this indeterminate structure. Exact calculation confirms values obtained by author's formula. No reference to practical use is made.

H. Beer, Austria

3206. Schindler, K., Beam on elastic foundation without allowance for tensional forces between beam and foundation (in German), *Öst. Bauzeitschr.* **11**, 3, 47-53, Mar. 1956.

The customary analysis of beams on elastic foundation is based on Winkler's theory (1867) which assumes that the reaction of the foundation is proportional to the deflection, acts vertically to the undeflected beam, and opposes the deflection. Hence, where the deflection is downward there will be a compression in the supporting medium, but where the deflection happens to be negative, tension will be produced. Winkler's assumptions were made in order to give a closed analytical solution to the problem.

Author develops equations on the assumption that there are no tensile forces between the beam and its foundation; thus the foundation is subjected to pressure only and the beam either sinks into the foundation or rises effortless from it. The beam length is then divided into regions where the deflection $y \geqq 0$ and $y \leqq 0$, and the differential equations are then established for the respective regions. The solution shows, e.g., that for a concentrated load the elastic line is only curved in a region adjacent to the load, while it is straight beyond that region, and that this region is 33⅓% shorter than that established by Winkler's theory. Furthermore, the bending moment and deflection calculated on the author's assumption (no tension) are 9% larger than that derived by the customary method. The bending moment is both positive and negative according to the present theory, while the author shows that for the case considered it is zero at the end of the region and does not change sign. These facts are very significant, especially when dealing with a system of both concentrated and equally distributed forces.

M. Maletz, USA

Plates, Disks, Shells, Membranes

(See also Revs. 3183, 3184, 3185, 3213, 3215, 3216, 3219, 3226, 3241, 3246, 3427, 3428)

3207. Hoeland, G., Influence fields of moment at supports in continuous elastic plates simply supported at both sides (in German), *Ing.-Arch.* **24**, 2, 124-132, 1956.

Influence fields have been solved for one-span plates (Bittner, Pucher, etc.). Only Bittner has looked into influence of neighbor panels in an approximate way. Present paper starts from Pucher's influence field of moment at transversal support in an infinite half strip. Hence, influence field of moment at transversal support is given for two mutually adjoining half-strip plates. Pairs of symmetrical and unsymmetrical rectangular plates are then studied, and influence fields of moment at intermediate (elastic and rigid) supports are given. A way is shown for solving influence fields of moment at supports in a continuous plate with many elastic transversal supports. Approximate solution recommended by DIN 1075 norm for symmetrical pairs of plates gives moments at supports up to 75% larger than those given by exact solution found in this paper.

H. Fernández Long, Argentina

3208. Woinowsky-Krieger, S., Application of bi-polar coordinates for the solution of a problem of bending of plates (in German), *Ing.-Arch.* **24**, 1, 47-52, 1956.

The expressions for the deflection and bending moments are derived for thin plates of uniform thickness with built-in edges. The plates treated have the following boundaries and a uniform loading: (1) two circular arcs; (2) a circular segment; (3) a half-circle; (4) a half circle under a hydrostatic load; (5) an eccentrical ring under a symmetrical load.

W. Ornstein, USA

3209. Brunner, W., Moment-distribution method for solution of continuous plates under uniformly distributed loads (in German), *Schweiz. Bauztg.* **73**, 50, 771-779, Dec. 1955.

Author extends the Cross method (or the moment-distribution method) to the solution of continuous plates that are subdivided into many rectangular panels by intermediate supports. The method is based on the assumption that the bending moment along each edge of the individual panel is distributed according to a

half sine wave. It will provide accurate results for panels of moderate length-width ratios under uniformly distributed loads.

Author includes tables for stiffness factors and carry-over factors for rectangular panels of various boundary conditions, and of length-width ratios extending from 1 to 2. Author also provides a table for estimating the bending moment at the center of a panel which is acted on by a sinusoidally distributed bending moment along one of its four edges.

An example is given to illustrate the detailed procedure of the proposed method. T. H. H. Pian, USA

3210. Kaczkowski, Z., Representation of the deflection functions of an infinite strip in closed form (in Polish with Russian and English summaries), *Arch. Mech. stos.* **5**, 589–628, 1954.

A solution of a problem of an infinite strip is usually given in terms of trigonometric series which converge rather slowly. For an infinite plate though, especially when loads are circularly symmetric, a solution in a closed form is easily obtained due to simple boundary conditions. In order to solve an infinite strip in a closed form the author makes it a special case of an infinite plate. Closed forms which author obtains are sums of series containing logarithmic expressions. The first article of this paper deals with the theory of summation of this kind of series. Author presents several examples for various loads and boundary conditions. In all of them solutions contain combinations of four basic functions in a closed form. It is very probable that many of the infinite-strip problems can be solved in terms of these four functions, which suggests desirability of tabulating them. T. Leser, USA

3211. Oravas, G., Analysis of collar slabs for shells of revolution, *Proc. Amer. Soc. civ. Engrs.* **82**, ST 2 (J. Struct. Div.), Pap. 916, 14 pp., Mar. 1956.

A spherical elastic dome is joined at its edge to inner flange of annular collar slab with I-shaped cross section. Flanges of collar slab rest on columns that provide no appreciable restraints to deformations of dome or slab. Axially symmetrical deformations of dome and collar slab are analyzed independently by existing theories of plates and shells, and condition of consistent deformations at junction is imposed. Repeated approximation procedure of relaxation type is used to solve problem. Numerical example is included. H. L. Langhaar, USA

3212. Rüdiger, D., Stresses and deformations of curved shells with a parallelogram as horizontal projection (in German), *Öst. Ing.-Arch.* **9**, 4, 265–273, 1955.

The problem is reduced to the solution of partial differential equations of the second order. Apart from the perturbation functions, these equations are identical to those given by H. J. Jellet [*Irish Acad. Trans.* **22**, p. 343, 1853] and A. Pucher [*Beton u. Eisen* **33**, p. 298, 1934] for computing the infinitesimal deformations and stresses in surfaces having a rectangular horizontal projection.

From author's summary by K. H. Swainger, England

Buckling Problems

(See also Rev. 3181)

3213. Capey, E. C., The buckling under longitudinal compression of a simply supported panel that changes in thickness across the width, *Aero. Res. Counc. Lond. curr. Pap.* 235, 19 pp. + 9 figs., 1956.

An exact analysis is given for simply supported and for clamped panels, made up of three strips, in which the central strip differs in thickness from the outer strips. The buckling condition is that a fourth-order determinant vanishes. The elements of this determinant are transcendental functions of the wave length and the buckling stress, and a solution has to be found numerically by trial and error. Nondimensional buckling curves show that in particular for simply supported panels the buckling stress for a given width and cross-sectional area may be increased if the central strip is taken thinner that the outer strips.

J. F. Besseling, Holland

3214. Cox, H. L., and Klein, B., Buckling and vibration of isosceles triangular plates having the two equal edges clamped and the other edge simply-supported, *J. roy. aero. Soc.* **59**, 530, 151–158 (Technical Notes), Feb. 1955.

Approximate solutions obtained by the method of collocation are presented for the lowest critical buckling load of an isosceles triangular loaded plate. Also, the fundamental frequency is given. The base of the triangle is simply supported and the other equal edges are clamped. From authors' summary

3215. Kosara, J., Diagonal stiffening of simply supported square plate submitted to shearing stresses, *Bull. Acad. Serbe Sci. Cl. sci. tech.* **13**, 4, 5–9, 1955.

Discussing the rigidity required for diagonal stiffeners of webs, author determines it from the usual condition that they become nodal lines of the web, when buckled by shearing forces, as if they were absolutely rigid. Expressing the surface of the buckled plate by double trigonometric series, author arrives at an infinite secular equation, solved by approximations.

In reviewer's opinion, the final formula can be very useful in design of large plate girders.

J. M. Klitchieff, Yugoslavia

3216. Shuleshko, P., A solution of some problems of the buckling of ortho-anisotropic plates under bi-axial and uni-axial loading using a reduction method, *Univ. Technol., School Civ. Engng., Austral. Bull.* 3, 14 pp., 1955.

Some solutions for the buckling loads of rectangular ortho-anisotropic plates with two opposite edges simply supported and other types of support on the other edges are obtained by comparison of the characteristic equations for the ortho-anisotropic cases to the characteristic equation for isotropic plates for which the roots are known. Equations ("reduction") are established for the relationship between the roots of the characteristic equations for the two cases. M. V. Barton, USA

3217. Clark, L. G., Buckling of laminated columns, *J. appl. Mech.* **22**, 4, 553–556, Dec. 1955.

Theory is developed for columns whose laminations, which may differ in thickness and material, are attached at intervals. It is essentially a "long column" theory with the laminations thickness small compared with the distance between attachment points. Two examples are presented with corresponding test data. Excellent agreement is obtained in the Euler range, with theory becoming high as the free length of the laminations approaches the "short column" region. C. M. Tyler, Jr. USA

3218. Hui, E., Buckling of twisted bars under compression (in German), *Öst. Ing.-Arch.* **9**, 4, 288–319, Nov. 1955.

Paper aims at the determination of the critical forces of centrally and constantly loaded straight bars whose cross section is constant, but whose principal axes are twisted in the unloaded state through an angle constant per unit length, as the center of gravity is shifted along the bar axis. Five conventional basic conditions of end support are treated; one of these, the bar hinged at both ends, has already been solved by Ziegler. The paper investigates the five cases in synthesis. As a system of coordinates, a moving system is assumed whose axis in the unloaded state coincides with the main axes of the cross section, and with the bar axis; that is, the coordinate system is advancing along the bar axis, rotated together with the cross section. In the loaded

state, the origin of the coordinate system is shifted together with the centroid of the bar, but the axes remain parallel with their original positions.

The equilibrium method is applied to the determination of the critical forces. Arc length s measured from the lower end point of the elastic line is chosen for independent variable. In the course of the investigation, s is identified with time, and the deformation of the bar is described as movement of the coordinate system shifted along the elastic line, small magnitudes of second order being neglected. Two differential equations of second order are set up, independent variables in which are projections of the velocity vector of translation of the coordinate system along the two principal axes.

The eigen values of the differential equation yield, in the conventional way, the critical forces as functions of flexural rigidities α and β, referred to the two main axis, and of angle of twist ω_0 per unit length of the bar.

After the general solution, the critical force of the bar of total twist τ is compared with the Euler force of the nontwisted bar, $D = k \cdot D_E$, where k is the characteristic ratio, function of τ. Highly and slightly twisted bars are separately treated.

In highly twisted bars independent of the conditions of end fixity, in case of $\tau \to \infty$, the result $k = 2k(1 + k)$ is obtained, where $k = \beta/\alpha$. If $k \to \infty$, $k \to 2$.

In slightly twisted bars, the critical force generally differs little from the Euler force. This does not hold, however, for very slender bars. On the basis of very cumbersome calculations, k graphs are plotted for the five cases investigated. The rate of twist increases the critical force in all five cases, and so much the more, the slenderer the bar. $D_{k\tau}$ is in twisted bars a function of the two J-s referred to the two main axes. If k (J max, J min) is large, the effect of twist is greater (D_E calculated on the basis of J min). Hereafter, correlations among critical forces for the five different cases are given; finally, the conditions are treated under which the results are fair approximations.

I. Korányi, Hungary

3219. **Zuk, W., Creep buckling of plates at elevated temperatures,** *J. aero. Sci.* **23**, 6, 610–611 (Readers' Forum), June 1956.

The method of analysis presented is a numerical method based on finite difference equations modified to account for creep strains and temperature softening of the material. The solution is an iterative one, predicting deformation of the plate with time, load, and temperature history. From author's summary

3220. **Klein, B., Rapid estimation of the elastic-plastic Euler buckling loads for simply supported tapered columns under varying axial loading,** *J. aero. Sci.* **22**, 12, 873–874 (Readers' Forum), Dec. 1955.

An important structural problem not given sufficient attention in the literature is the buckling of tapered columns attached to sheet with consequent variable axial loading. Various methods exist for the calculation of these buckling loads. The approximate method presented here is direct, very rapid, yet sufficiently accurate and particularly suited for design. The assumed shear flow need not be constant in magnitude. From author's summary

3221. **Sechler, E. E., Inelastic buckling—from a designer's viewpoint,** *J. aero. Sci.* **23**, 5, 500–506, May 1956.

Paper discusses available information on inelastic buckling for columns, plates, and shells. Position with regard to plastic buckling of columns is considered satisfactory and basic concepts with regard to creep buckling of columns have also been established. Much information is available on plastic buckling of plates but additional test data, particularly for shear buckling, would be valuable. Much less is known about shells loaded beyond proportional limit, and inelastic buckling with creep for plates and shells is in the first stage of exploration. Author concludes that research workers should find here an extremely fruitful field for research in the next few years.

W. T. Koiter, Holland

Joints and Joining Methods

3222. **Niskanen, E., On the distribution of shear stress in a glued specimen of isotropic or anistropic material,** State Inst. for tech. Res., Finland, 25 pp., 1955.

Reviewer is happy to see this addition to the scant literature available to guide the designer in adhesive joint stress analysis. Author examines stress distribution in variously proportioned wooden glued joints, of single- and double-shear types used in adhesive testing. Under suitable assumptions for specimen loading, approximate isotropic and anisotropic (birch timber) plane stress solutions are found by Fourier analysis, omitting effect of adhesive layer stiffness. Latter is probably valid when layer is sufficiently thin and rigid, as in practice. Results are chiefly for double-shear specimen; glue-line shear stress for anisotropic case is quite different from isotropic case, former being generally more uniform along the joint. J. L. Lubkin, USA

3223. **Demarkles, L. R., Investigation of the use of a rubber analog in the study of stress distribution in riveted and cemented joints,** *NACA TN* 3413, 97 pp., Nov. 1955.

Author's exploratory experiments show that useful information about such joints can be obtained by loading foam rubber models within their linear range. To quote: "All deformations are greatly exaggerated..... and effects that might pass entirely unnoticed in a metal specimen show up as factors to be considered when seen in rubber." For adhesive joints, strains and stresses in the loaded models are approximated by measuring the displacements of a grid of squares drawn upon the surface of the models before loading. In the riveted models the grid is replaced by an array of lead nitrate-soaked threads, and by slender metal rods; displacements are obtained from x-ray photographs. Deformations and stresses are depicted and discussed at length. The test results and conclusions may not be wholly representative of conventional joints: however, (1) although still in the linear range, the models sustain large strains, which the originals generally do not; (2) as author notes, foam rubbers do not constitute perfectly analogous materials when compression and shear (or both) are significant; (3) in the case of cemented joints, the models were bonded with a type of latex adhesive having properties similar to the foam rubber (thus, conclusions may not be valid for the usual metal-metal joint, which employs adhesives considerably more flexible than the adherends).

A stress analysis of an adhesive lap joint is given in an appendix; this is similar to Volkersen's, but makes approximate allowance for adherend shear, as well as the adhesive shear and adherend tension considered by Volkersen. Adherend bending and adhesive transverse normal stresses are omitted here. Considering the various approximations involved, the analysis gives reasonable agreement with the adhesive shear stresses found from the rubber model, in the range of linear deformations. However, reviewer feels that author errs in trying to apply a theory which assumes linear adhesive elasticity to the analysis of lap joint *failure* tests, without giving further justification. This is because there is evidence that highly inelastic behavior of the adhesive may be expected under these circumstances [see "A strain gage for the measurement of strains in adhesive bonds," by C. B. Norris, et al., *For. Prod. Lab. Rep., U.S. Dept. Agric.* No. TM-92, rev. Aug. 1955; also AMR **9**, Rev. 1786]. Author's procedure amounts to curve-fitting the linear theory to the failure test data, thereby deriving "effective" values of some parameter, such as adhesive shear modulus. This is perhaps justifiable for design purposes when it is conservative, but author shows that it may be unreliable.

Reviewer believes it better to design directly from test results, until a more systematic design procedure has evolved (preferably one taking account of adhesive inelasticity).

Author also gives an order-of-magnitude discussion of the effect of adherend bending on adhesive stresses in lap joints.

J. L. Lubkin, USA

3224. Vreedenburgh, C. G. J., New principles for the calculation of welded joints, *Inter. Shipbldg. Progr.* **1**, 4, 200–223, 1954.

Results of static tests carried out by the Netherlands Foundation for Applied Scientific Research are compared with Kist's method of analysis, now adopted in the Netherlands specifications, and with results based on other limiting-stress theories. It is concluded that no known limiting-stress theory can explain the experimental results and it is proposed to adopt a purely empirical surface of revolution ("pearoid") as surface of limit stresses. New proposal gives some simplification and economy compared with Kist's method. Reason for failure of theories is thought to be nonuniform stress distribution in weld. For fatigue loading, a tentative proposal is also made.

F. J. Plantema, Holland

Structures

(See also Revs. 3194, 3201, 3205, 3213, 3217, 3221, 3245, 3248, 3251, 3255, 3269, 3272, 3274)

3225. King, J. W. H., and Jenkins, D. E., Effect of a stiff-jointed frame on its plastic collapse load, *Engineer, Lond.* **201**, 5229, 320–323, Apr. 1956.

In the ordinary theory of plastic analysis it is assumed that the collapse load is not affected by the change of the structure geometry, necessary to develop the plastic moments of resistance. Purpose of this paper is to give an outline of a method introducing the effect of frame distortions in the plastic analysis, and to show that distortions tend to decrease the collapse load under the lower bound of the ordinary theory.

In order to illustrate the application of the proposed method, the analysis of a double-bay, single-story frame is given. In the equilibrium equations are introduced the moments caused by the frame distortion. The working-out of the equilibrium equations to find the exact solution is not given, but the results are quoted. To simplify the analysis, an approximate solution is derived, taking into account only first-order displacements.

The results are given in graphical form. The collapse diagram is given as an enclosed figure that represents plastic collapse in all its modes. Three diagrams are plotted: (a) Neglecting distortions; (b) assuming a distortion 10% of the column height, or a beam deflection 10% of the beam half span, and using the exact solution; (c) using first-order correction only. Diagrams are given for another four cases, including a portal frame carrying a distributed load. From the diagrams it is possible to conclude that, except in a small part of one diagram, the distortions tend to decrease the collapse load, and that first-order analysis gives practically the same results as the exact solution, at least for the assumed 10% distortions.

In reviewer's opinion, the paper has a valuable theoretical interest, but from the practical point of view it has a limitation in the process of finding the distortions when the collapse is imminent. To do an accurate analysis would be a considerable task, not justified if we consider that a precise calculation depends upon many theoretical assumptions not fulfilled in practice. If we ponder that the strengthening action of strain-hardening, present in varying degrees for different structures, tends to compensate the weakening effect of distortions, the influence of displacements would be of interest only in the case of very slender frames.

C. A. Sciammarella, Argentina

3226. Little, G., and Rowe, R. E., Load distribution in multi-webbed bridge structures from tests on plastic models, *Mag. Concr. Res.* **7**, 21, 133–142, Nov. 1955.

A multiwebbed bridge structure is one which is intermediate between the two extreme cases, i.e., a no-torsion grillage and a full-torsion slab, considered in the load-distribution analyses. The theoretical interpolation formula which gives the distribution factors for this type of construction has been established by this reviewer (I.A.B.S.E. Publications, Zurich, Vol. 10, 1950, pp. 147–188). It makes use of a torsion parameter, α.

Present paper gives the results of tests conducted on perspex bridge models, in order to determine the correct value of the α parameter to be consistent with the assumptions of theoretical analysis. It is concluded that excellent agreement with theory is obtained if the torsional rigidities are derived from consideration of only one cell of the over-all section of the bridge. This conclusion applies to multiwebbed beam and slab bridges as well as to multicell box-section bridges. For this second type of bridge, one obtains erroneous values of parameter α by basing its calculation on the torsional stiffness of the entire multiweb box section, determined, e.g., by Wittrick's formula [AMR **7**, Rev. 1059].

C. Massonnet, Belgium

3227. Eisenmann, J., Iterational calculation of multistory frames with sidesway (in German), *Bauingenieur* **31**, 2, 61–67, Feb. 1956.

Paper is a further development of a method formerly published by the author [*Bauingenieur* **28**, 6, 198–199, June 1953]. The introduction establishes a relation between the difference Δx of sidesway of two contiguous stories of the frame and the horizontal load acting on that story. The derived formula also includes the angular rotations φ arising at the column ends of the story investigated, which are unknown for the time being. Therefore the differences Δx of sidesway are determined by iteration. The first step of the iteration takes into account the angular rotations φ with zero value or with some approximate value φ', whereby the first approximate values of displacements Δx are obtained. Afterward, the column end moments are calculated, whereupon moment distribution is executed at the joints. With the approximate moment diagram of the frame known, the initial values φ' of the angular rotations at the column ends can be corrected and thereby a point of start is found for the second step of the iteration. By continuing the procedure in similar steps, the values of Δx and φ can be determined with any wanted precision.

The convergence of the computation can be essentially increased—and this is the only novelty over the afore-mentioned study of the author—if in the first step the angular rotations φ are assumed, instead of zero, with some more accurate values. For the determination of these initial values, the original structure is substituted by a structure made statically determinate, and the angular rotations at the joints of this structure are taken as initial values of φ'. The substitute structure is obtained from the original one by inserting hinges in a way that the deformation of the substitute is similar to that of the original structure. Some errors of sign are corrected by the author in *Bauingenieur* **31**, 4, p. 156, Apr. 1956.

P. Csonka, Hungary

3228. Schenker, L., The dynamic response of tall structures to lateral loads, *Proc. Amer. Soc. civ. Engrs.* **82**, EM 2 (*J. Engng. Mech. Div.*), Pap. 944, 13 pp., Apr. 1956.

Author shows how to calculate normal modes of vibration using stiffness matrix and how to calculate damping coefficients when damping in each mode is known. Numerical examples of each method are presented.

G. W. Housner, USA

3229. Clough, R. W., On the importance of higher modes of vibration in the earthquake response of a tall building, *Bull. seism. Soc. Amer.* **45**, 4, 289–301, Oct. 1955.

Author presents numerical analysis of vibration of a tall building due to actual earthquake shock to evaluate maximum shear forces in each of the stories. Vibration mode shapes and frequencies of the building, which had been analyzed by Robin and Rinne, were used as the basis of study, and response curves were computed not only for the fundamental mode but for second and third modes of vibration. Author defines effective values of response parameters for each vibration mode and computes total maximum shear forces, assuming combination of damping coefficients for the three modes. It was found that consideration of second and third modes of vibration means more than a small amount of increase in maximum shear forces in the building and that magnitude of forces in lowest story becomes larger than those specified by building codes. K. Kasahara, Japan

3230. Koiter, W. T., A new general theorem on shakedown of elastic-plastic structures, *Proc. k. Ned. Akad. Wet.* (*B*) **59**, 1, 24–34, 1956.

Further simplification of the proof of Melan's theorem on shakedown is first provided, followed by a proof that if the conditions of Melan's theorem are satisfied, the total amount of plastic work done on the structure is bounded. Author then proves a new theorem of shakedown, based on concept of "admissible plastic strain rate cycle," which has property that plastic strain changes in one cycle are compatible, i.e., correspond to displacement increments. Stated in (reviewer's) words new theorem is: "Structure will *not* shake down, but will fail by plastic collapse under cyclic loading, if any admissible plastic strain rate cycle exists for which the work done by external loads in one cycle exceeds the plastic work done; on the other hand, structure will shake down if, for all admissible plastic strain rate cycles, the work done by external loads per cycle is less than the plastic work done." New theorem furnishes method for finding upper bound for shakedown load limits, contrasting with lower bounds furnished by Melan's theorem.

Reviewer notes that for beams and frames an upper bound theorem of much simpler form and proof has already been applied, using the technique of combining elementary mechanisms as in collapse analysis; see paper by reviewer and Neal, AMR **5**, Rev. 2010. P. S. Symonds, USA

3231. Jablecki, L. S., Analysis of the premature structural failures in static tested aircraft, *ETH, Zürich Prom.* 2209, 101 pp., 1955.

Author has had access to 409 static tests on aircraft components (wing and fuselage assembly; horizontal and vertical stabilizer; and landing gear) for the period 1940 to 1945, in which wing assemblies showed 56% failure expectancy, while the least was for the vertical stabilizer with 23%. Results are of value to aircraft designers. Additional tests were conducted by author on long spliced riveted joints (one plate-two straps) in tension, using wire strain gages along the straps to note load distribution by each rivet. Some tests were made on 20-rivet, but majority of interpretations were on 10-rivet, joints.

Author concludes that load transfer should be made as rapid as possible to prevent end rivets from deforming too far in plastic range. Rivet load distribution was not linear. Plots based on percentage of ultimate load versus failure expectancy enabled author to detect good stress analysis and close designing; to detect overdesign; and to show mistakes in analysis.

This doctorate dissertation contains numerous photographs and sketches indicating areas of frequent failures. References are not extensive, especially on riveted joints where passing comment is made to repeated loads. Appendixes contain detailed summary of static test results and nomenclature. H. Majors, Jr., USA

3232. Farinha, J. S. B., Calculation of structures depending on the degree of constraint imposed by foundations (Symposium of foundations, Pap. no. 1) (in Portuguese), *Bol. ord. Engenheiros* **5**, 8, 6 pp., 1956.

A direct simple analysis of a problem of foundations in which complete and partial constraints are applied to superimposed structures. A detailed example is developed and solved for illustrating methods proposed. J. M. DallaValle, USA

3233. Franciosi, V., Limit analysis for nonproportional loading (in Italian), *Ricerca, Napoli* **5**, 3, 23–28, 1954.

For expository reasons, the determination of the load factor of a structure by limit analysis is usually discussed as if a common load factor applied to all loads [see, however, H. J. Greenberg and W. Prager, *Trans. Amer. Soc. civ. Engrs.* **117**, 481–482, 1952]. The present author points out that these methods are readily extended to the case where the load factor is applied only to some loads while the intensities of the other loads are fixed. W. Prager, USA

3234. Morgan, V. A., Analysis of a parabolic arch of uniform thickness, *Concr. constr. Engng.* **51**, 4, 335–343, Apr. 1956.

General equations are derived which can be used in the design of arches of any rise-span ratio. The most usual case, where the rise is one-quarter of the span, is used here, and the stiffness ratios, carry-over factors, arch thrust, etc., are derived for this ratio to simplify the calculations. The properties of arches with other rise-span ratios can be calculated from the equations derived. From author's summary by A. H. Finlay, Canada

Book—3235. Kani, G., Prestressed concrete—its design and construction [Spannbeton in Entwurf und Aüsfuhrung] Stuttgart, Verlag Konrad Wittwer, 1955, xii + 573 pp. DM. 45.

Author first works out differences between concrete, reinforced concrete, reinforced concrete with pretensioned steel, and prestressed concrete, and shows the new principle of the latter. His calculation of the creep rests upon a constant worth of material $K = \sigma/\epsilon_\infty$, wherein σ means the tension and ϵ_∞ the deformation in consequence of creep without elastic and shrinking deformation. Based on the researches of Freyssinet on shrinking, author calculates shrinking deformation with $\epsilon = \sigma^{kap}/K$, wherein σ^{kap} means the capillary tension in the pores of concrete filled with water and K the same constant worth as above. After speaking about the elastic and plastic qualities of prestressing steel, author discusses the bonded material prestressed concrete in two examples: a truss post and an experimental beam loaded to failure. Description follows of the different prestressing methods used in Germany [see Möll: "Spannbeton"; AMR **8**, Rev. 81.]

The next chapters treat statically determined beams and continuous beams. Design formulas are given for the first, and a detailed example is computed for the dimensioning of the latter. The problem of the frictional losses in prestressing elements is shown, and an instruction is given on measuring the frictional coefficient during prestressing work. After chapters about the principal tensile stresses and the bond stresses, author shows an approximate method for the calculation of the ultimate moment. Further, he treats bond action of concrete and prestressing elements. Finally, some constructive peculiarities are described which have to be considered when a prestressed building is designed.

The qualities of the basic construction materials are explained only briefly, as they can be found in many other books. In contrast, a complete view is given for the methods of calculation and dimensioning and the construction principles. Author, having constructed large buildings of prestressed concrete himself, states general rules as well as his own thoughts in clear terms so that the book is not only useful for consulting but also for study. G. Brandes, Germany

3236. Sievers, H., State of stress in the region of anchoring plates of stressed elements in prestressed concrete constructions (in German), *Bauingenieur* **31**, 4, 134-135, Apr. 1956.

Author makes use of an earlier proposed equation for the positions of the resultant compression forces in the anchoring plate due to the loading by two equal and symmetrical single forces [AMR **6**, Rev. 89]. In that paper, author replaces the usually assumed parabolic curve by an exponential curve. The length of the disturbed region is assumed to be equal to the height d of the anchoring plate. The proposal yields the result that the steel reinforcements which carry the tension forces normal to the load direction should be concentrated in a region smaller than $0.2d$ from the outer surface of the plate. Author extends these considerations for antisymmetrical and unsymmetrical loading conditions and gives in each case the equation for the resultant tension force acting in the reinforced-concrete plate.

F. M. Mueller, USA

3237. Nikitin, Ya. A., Examples of spillways damaged by silt load (in Russian), *Gidrotekh. Stroit.* **22**, 10, 12-14, 1953.

3238. Mironov, S. A., Frost resistance of concrete for hydraulic work (in Russian), *Gidrotekh. Stroit.* **23**, 1, 35-39, 1954.

3239. Howe, D., An approximate solution to the swept wing root constraint problem, *Coll. Aero. Cranfield Rep.* 98, 14 pp. + 1 fig., Feb. 1956.

Author considers sweptback rectangular box beam with stringers and spar booms and closely spaced rigid ribs. Using oblique coordinates, he assumes the spanwise direct stress in the skin to vary parabolically in chordwise direction, the coefficients of the quadratic expression in the chordwise coordinate being three undetermined functions of the spanwise coordinate. By using Castigliano's theorem of minimum strain energy he derives second-order differential equations for these functions. Solution of these, author claims, agrees with experimental results for the root constraints.

D. Williams, England

3240. Stein, M., and Sanders, J. L., Jr., A method for deflection analysis of thin low-aspect-ratio wings, *NACA TN* 3640, 65 pp., June 1956.

In case of a low-aspect-ratio wing, bending and torsion are not uncoupled, and there appears the additional complication of chordwise bending. Authors present method for obtaining influence coefficients for thin low-aspect-ratio wings of built-up construction. Chordwise deflections are assumed to be parabolic (or linear) and the principle of minimum potential energy is used in conjunction with difference equivalents to obtain an appropriate set of equilibrium equations. Symmetric and antisymmetric load-support conditions are considered and account is taken of attachment to a flexible fuselage. Computations in matrix forms are suitable for high-speed computing machines. Reference is made to previous research in this field by S. Levy, H. U. Schurch, D. Williams, R. H. MacNeal, and E. Reissner.

J. J. Polivka, USA

3241. Broglio, L., Balance method in advanced aeronautical structures analysis, Univ. Roma, Scuola di Ingegneria Aeronautica, Rome, SIARgraph no. 2, 169 pp., Feb. 1955.

In monocoque aircraft, tapered shells reinforced with longitudinal stringers frequently occur. Up to now, existing methods of analysis have been too inexact or too cumbersome for efficient practical design. This report shows how to apply a "balance method" (developed in a previous report, no. 1 of the series) to these highly redundant structures. The method consists of dividing the applicable equations into two groups; those in the first state Hooke's law and the static equivalence of the stress distribution to the external loads, and the second includes the remaining equations of equilibrium. The problem is then reduced to the superposition of two other loadings, one of which consists of locally balanced groups of forces. The other is deduced from an assumed distortion parameter by successive application of the two sets of equations, and determines the first, which problem is then solved by successive approximations. The entire solution is thus reduced to a series of simple numerical operations.

The method is applied to shells with four stringers, to bisymmetric shells with many stringers, and to unsymmetrical rectangular box sections. Numerical examples and graphs are included.

A. D. Topping, USA

3242. Cadambe, V., and Krishnan, S., Note on the minimum-weight design of thin-walled cells in combined bending and torsion, *J. roy. aero. Soc.* **60**, 541, p. 71 (Technical Notes), Jan. 1956.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3219, 3220, 3230, 3233, 3256, 3452)

3243. Drucker, D. C., On uniqueness in the theory of plasticity, *Quart. appl. Math.* **14**, 1, 35-42, Apr. 1956.

Paper discusses uniqueness of general boundary-value problem for various elastic-plastic materials. After reviewing existing uniqueness proofs, author sketches an alternative viewpoint and a "proof in words." Reviewer could not follow reasoning and deplores author's failure to express his ideas and proof precisely in mathematical terms so that adequate assessment and discussion are possible.

Argument appears to depend in part on a previous "basic thermodynamic postulate" of author: if *additional* forces are applied to an *already loaded* work-hardening solid and are then removed, the work done by these *additional* forces in such a cycle can never be negative. Reviewer knows of no general thermodynamic principle relating to the work done by only *some* of the acting forces and finds the postulate without compulsion. Author claims that postulate validates conventional assumption that plastic strain-rate vector is normal to yield surface; reviewer considers that one assumption has merely been replaced by another without any apparent advantage.

R. Hill, England

3244. Wahl, A. M., Analysis of creep in rotating disks based on the Tresca criterion and associated flow rule, *J. appl. Mech.* 23, 2, 231-238, June 1956.

This paper presents a correlation of actual creep in rotating disks with theoretical analyses. Of the three analytical procedures used, two are considered to be of practical value. The first is based on the maximum shear, or Tresca criterion, and the second combines the flow rule associated with the maximum shear theory. The second method is shown to be much simpler to use, but in reviewer's opinion it does not produce as good a correlation as the first method. The second method yields curves of different shape than the actual data, and while crossing the actual data scatter bands at certain points, extrapolation would be extremely dangerous. Disks under three conditions are considered: (a) Constant temperature and constant thickness; (b) constant temperature and variable thickness, (c) variable thickness and variable temperature.

The analyses are applied to steady-state conditions as well as to transient changes in stress. Good correlation is evidenced especially with the first method. Although it is realized that they

represent only an approximate solution, both methods are considered by the author as usable to provide design data.

A. D. Schwope, USA

3245. **Rozenblum, V. I., Calculation of creep of a diaphragm in high-pressure stage of a turbine** (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **20,** 49-54, 1954.

Author correlates approximately the creep behavior of a rod in simple tension test with that of combined stress in a semicircular ring plate supported at the outside edge and loaded by a constant normal distributed load. Such a plate is a model of a turbine diaphragm.

The author derives: (1) Formula for normal tensile stress σ_0 in the plate which corresponds to the tensile stress in the test rod; (2) formula for creep rate z_0 corresponding to σ_0; (3) formula for maximum deflection rate u_{max} for a given z_0. Deflection S of the plate at a time t is, of course, $S = u_{max}\, t$.

T. Leser, USA

3246. **Grigor'ev, A. S., Bending of circular and annular plates of varying thickness beyond the limits of elasticity** (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **20,** 59-92, 1954.

Author investigates plates described in the title in axisymmetric conditions of loading and support. The normal loads are constant and distributed and a number of cases, where plates are of constant thickness, of variable thickness, are freely supported or rigidly supported, are dealt with separately. Plates are made of material which does not possess a yield region. Author derives equations for deformations and stresses in the plastic region which can only be applied to that part of the plate which is in plastic equilibrium; hence the necessity to determine which part of the plate is in elastic equilibrium, and which in plastic equilibrium. Thus the author had to find a criterion for that. Solutions in closed form are approximations; more exact solutions can be obtained numerically. Analysis of error and conditions under which author's method is applicable are also presented. T. Leser, USA

3247. **Berio, A., An elastoplastic-viscous phenomenon of solids** (in Italian), *Ist. Lombardo Sci. Lett. Rend. Cl. Sci. Mat. Nat.* (3) **18 (87),** 295-355, 1954.

The paper begins with a survey of stress-strain laws proposed by various authors to describe the isothermal mechanical behavior of solids. The present author seems to object to the fact that each of these laws stresses some effects and neglects others. He proposes, instead, a single law that incorporates elastic after-effect, viscosity, and plasticity including work-hardening and Bauschinger effect.

W. Prager, USA

3248. **Horne, M. R., The elastic-plastic theory of compression members,** *J. Mech. Phys. Solids* **4,** 2, 104–120, Feb. 1956.

Expressions are derived for curvature of initially straight prismatic members of ideally-plastic material with upper and lower yield point and of rectangular cross section subjected to axial load and bending moment. Results are applied to analysis of eccentrically loaded struts with pinned ends, fixed ends, and elastically restrained ends.

It is shown that, for pinned ends, collapse load of struts is close to yield load for slender members and somewhat above this load for stocky struts. For fixed ends, collapse load bears no relation to yield load. G. G. Meyerhof, Canada

3249. **Gol'denblat, I. V., Theory of small elastoplastic deformations of anisotropic media** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 2, 60–67, Feb. 1955.

Author points out Ilyushin contributions which formed the background for this investigation. According to Ilyushin, anisotropy is a cardinal factor in the development of deformations under a composite loading. Author states that the use of anisotropic materials in contemporary technology would require generalizations in the theory of small elastoplastic deformations for anisotropic media. Before this theory could be developed for materials with variable anisotropy one should start with constant anisotropy. Author reviews certain general relationships for isotropic and anisotropic media. Further, author considers that presently this theory is based on two fundamental propositions from which may be derived all the equations pertaining to this subject. The first of these laws implies that the volumetric deformation is elastic in a sense of classical theory of elasticity; and the second law assumes the existence of a strain potential. Author indicates that the stress intensity is a function of strain intensity only. Hence the strain curves must be on a cylindrical surface. Author presents relationships for the theory of small elastoplastic deformations. Originally these equations were given by Ilyushin. Author develops a second form of these equations which, in mathematical sense, are equivalent to the first form except that the second form is more convenient for transformation into anisotropic media. Author employs general properties of tensors for the development of the relationships for the small elastoplastic deformations of anisotropic materials and also discusses invariants and the uniqueness of tensors pertaining to this problem. V. A. Valey, USA

3250. **Tyabin, N. V., Theory of anomalous viscosity in dispersion systems** (in Russian), *Zh. tekh. Fiz.* **25,** 2, 339–350, Feb. 1955.

Paper considers characteristics and classification of non-Newtonian fluids with a general dependence of shearing stress on transverse velocity gradient. The general relation is approximated by several segments of straight lines, each leading to a viscosity (slope), and a "critical stress" (abscissa of point of intersection with segment to left on conventional diagram). Paper proceeds to develop the application of this representation to Poiseuille flow and gives (the rather trivial) explicit formulas for velocity profiles and rates of flow for a two-segment, a three-segment, and an n-segment approximation. J. Kestin, USA

Failure, Mechanics of Solid State

(See also Revs. 3224, 3231, 3237, 3256, 3459)

3251. **Paoli, R., Nuclear explosions and strength of material** (in French), *Ann. Ponts Chauss.* **126,** 2, 127–162, Mar.–Apr. 1956.

Author reviews and summarizes a large number of mathematical relationships that relate to the effects of bomb blasts against structures. In each case he goes to considerable effort to provide background material on how the relationship was established. The compilation should prove extremely useful and illuminating to anyone concerned with the design of structures to withstand blast.

J. S. Rinehart, USA

3252. **Chenea, P. F., and Roach, A. E., A mass and energy balance for the wear process,** *Lubrication Engng.* **12,** 2, 123–125, Mar.–Apr. 1956.

After deriving an analytical expression for the rate of wear on the assumption that densities of the original material, the worked surface, and the wear particles are approximately equal, authors conclude that "as might be expected, it is necessary to introduce a very small coefficient on the right side in order to obtain reasonable agreement with experimental data." In fact, experimental evidence is available that, in the region of the validity of Amontons' law, the work spent on abrading matter is a small proportion of the total frictional work. R. Schnurmann, England

Material Test Techniques

3253. Strella, S., Vibrating reed test for plastics, *ASTM Bull.* no. 214, 47–49, May 1956.

Author describes a new vibrating reed method for obtaining the dynamic modulus of solid plastics.

From author's summary

3254. Barwell, F. T., Methods of testing reinforced plastics, Parts I and II, *Aero. Res. Counc. Lond. Rep. Mem.* 2702, 34 pp., 1954.

An experimental comparison has been made between five types of tensile tests including novel types designed to enable axial loading conditions to be approached more readily than is the case with established methods. Examination of the results of two hundred and forty tests indicates that significant differences can occur between the results of different tests and that there is also a significant variation between the properties of material cut from different parts of the same sheet.

It is concluded that the results, obtained when testing paper-base material by novel methods, are sufficiently good to justify development of a simplified apparatus of similar type for general use.

From author's summary

3255. Botman, M., Shear tests on 24S-T unstiffened and stiffened webs with flanged holes. Part 2, *Nat. LuchtLab. Amsterdam Rap.* S.446, 33 pp. + 19 tables + 38 figs., 1955.

Report contains the results of tests on 32 specimens, being an extension of the tests described in AMR **7,** Rev. 1769.

The same test methods were employed. The buckling, yield, and ultimate allowable stresses are presented in the form of nondimensional diagrams. The initial effective modulus of rigidity is also determined. Results are compared with the results of tests on 52 specimens described in AMR **7,** Rev. 1769, and with the results of comparable tests on 84 other specimens. The agreement is in general good, except for the effective modulus of rigidity.

From author's summary

3256. Tabor, D., The physical meaning of indentation and scratch hardness, *Brit. J. appl. Phys.* **7,** 5, 159–166, May 1956.

Indentation testing is an essential tool in control of engineering production. Yield strength of metals can be measured nondestructively by small plastic indentations using hard indenters. Pyramidal (e.g., Vickers, Firth, Knoop) and conical (Rockwell, Avery) indenters give hardness values sensibly independent of penetration, through geometrical similarity of impressions. Spherical (e.g., Brinell) indenters give results dependent on penetration at larger penetrations, from which work-hardening ability of metal can be estimated.

Author shows Vickers hardness number is experimentally about three times yield stress of metal; also that in work-hardening metal the average strain (always constant) caused by pyramidal indenter may be approximately added to work-hardening (longitudinal) strain originally present.

Author's relation of the Mohs 10-step mineral scratch-hardness scale to measured indentation hardnesses is of interest. Users of the Mohs scale might now profitably consider its replacement in the laboratory by indentation-hardness measurements which can be precisely measured.

Reviewer notes author's experiments show indentation pressure (Vickers square pyramid) is about 6.0 × shear strength of metal (shear strength ≈ 1/2 yield strength in compression or tension). This may be compared with theoretical values of 5.69 × shear strength for a smooth flat circular punch on a flat plastic-rigid surface, and Prandtl's value of 5.14 × shear strength for a flat long strip punch. Author's quoted comparisons between Vickers and Knoop (elongated pyramid) hardnesses on minerals suggest Knoop hardness is about 80% of Vickers hardness, corresponding to about 4.8 × shear strength. This seems a low result, being below even Prandtl strip value of 5.14 times, but is partly accounted for by Knoop impression being seven times its width.

Further experimental and theoretical work is desirable to relate yield stress hardness number ratio more precisely to various shapes of indenter, and to the failure strain and work-hardening properties of the metal.

Value of paper would be enhanced by consideration of effects of different ratios of Young's modulus to shear strength. In allied field of soil mechanics, that ratio has been shown [Skempton, Build. Research Congr., Div. 1, p. 183, 1951] to exercise marked influence on penetration resistance.

T. K. Chaplin, England

Mechanical Properties of Specific Materials

(See also Revs. 3222, 3223, 3238, 3254, 3256, 3397, 3452)

Book—3257. Miner, D. F., and Seastone, J. B., Handbook of engineering materials, New York, John Wiley & Sons, Inc,; London, Chapman & Hall, Ltd., 1955, xi + 1380 pp. $17.50.

This is a valuable addition to the Wiley Engineering Handbook Series. It covers a remarkably broad field considering its size, which is comparable to that of the "Handbook of engineering fundamentals" edited by Esbach. The method of indexing is not unlike that of Esbach and appears to be very adequate.

Due to compactness, it does not pretend to be as complete as other individual references which specialize in particular classes of material. Nevertheless, the thoroughness with which it has managed to cover all types of engineering material should make it an invaluable sourcebook for every engineer.

It is divided into four major sections, namely: (1) General information, (2) Metals, (3) Non-metals, (4) Construction materials.

The first section covers the fundamentals of materials specification and the physical properties of gases, liquids, and solids. It includes an outline of statistical sampling methods as well as definitions of the various arbitrary gaging systems for wire and sheet metal. Conversion tables are included between various dimensional systems for all conventional engineering quantities.

The section on metals has individual articles on the ferrous group, aluminum, magnesium, copper, zinc and nickel, as well as a separate article covering the basic property of all other pure metals. This last section is worthy of special mention because it includes brief statements on the source of supply, approximate cost, availability, and properties of even the very rare metals; for example, cesium, hafnium, etc., which are not likely to be readily available to the nonmetallurgical engineer.

Information is given on the important properties of metals, including methods of fabrication, machinability, etc., as well as heat-treating techniques, joining techniques, alloys, and physical characteristics such as chemical, electrical, and corrosion properties. The degree of detail is roughly proportional to the industrial use.

The section on nonmetals is remarkably comprehensive considering that it comprises only 500 pages. Materials covered include wood, paper, fibers, plastics and rubbers, fuels, lubricants, industrial chemicals, ceramics and glass, carbon products, and organic finishing materials such as paints. The data in this section are comparable to those of the metals section insofar as the same techniques are applicable. Structural properties, temperature characteristics, basic chemistry, electrical properties, etc., are included. In general, sensitivity to decay, fungus attacks, etc., tend to replace data on corrosion.

The final section includes basic data on construction materials such as concrete, timber, rope, and asphalt, while it outlines the

principles for using these materials in civil engineering construction such as highways, buildings, foundations, etc.

Reviewer recommends the book highly as a general source.

C. D. Pengelley, USA

3258. **Bhagavantam, S., and Murty, Y. K., Temperature dependence of photoelastic constants in plastics,** *Proc. Indian Acad. Sci. (A)* **42,** 4, 203–209, Apr. 1956.

Mechanics of Forming and Cutting

(See also Revs. 3231, 3387)

Book—3259. **Blanpain, E., Theory and practice of cutting tools [Theorie et pratique des outils de coupe],** Paris, Editions Eyrolles, 1955, 642 pp. 4,300 Fr.

The book is a kind of machine shop encyclopedia. Its theoretical part describes successively: tool geometry, materials and fabrication, (including heat treatment); machinability and tool wear; chip-breakers and selection of best machining conditions. Its practical part discusses various machining operations: turning and tread cutting; planing and shaping; drilling, reaming, tapping, and milling; scrapping and broaching. The book ends with a discussion of cutting fluids, tool grinding and trouble shooting.

An asset of this book (winner of the first prize granted for a technical book by French Federation of Mechanical Industries) consists in the systematical survey of most important machining problems. This survey attempts to build a bridge between machining theory and practice and can help any tool or production engineer a lot; this in spite of the fact that bibliographical references are rather lacking and that some interesting points are not stressed enough (tool wear by micro-weldability; film lubrication; tool life criterion; tool housekeeping). French and American contributions to machining knowledge are stressed; some German, British, Swiss, and even Russian contributions are also listed.

A. Niedzwiedzki, USA

3260. **Hahn, R. S., The relation between grinding conditions and thermal damage in the workpiece,** *Trans. ASME* **78,** 4, 807–812, May 1956.

Based upon observations concerning the influence of grinding variables on the thermal damage in workpiece, author formally proposed a "rubbing-grain" hypothesis for grinding. Among the several experimental evidences analyzed are: (1) Lower surface temperature accompanied by high work speed; (2) lower ratio of tangential to normal force of the grinding grit as compared with that of a single-point tool; (3) higher rate of metal removal with a fast dressed wheel; and (4) the effects of wheel-work conformity. The basic features of the hypothesis were introduced in an earlier paper by the author [AMR **9,** Rev. 770].

The "rubbing-grain" hypothesis differs, in many respects, from the conventional theory which treats the grinding process as essentially a milling process, but on a microscopic scale. However, as pointed out by Dr. Reichenbach, one of the discussers of the paper, nearly all the phenomena observed by author could be explained satisfactorily by the conventional theory.

B. T. Chao, USA

3261. **Colwell, L. V., The effects of high-frequency vibrations in grinding,** *Trans. ASME* **78,** 4, 837–846, May 1956.

Paper deals with a pioneering study of the influence of high-frequency vibration in grinding. The work specimens are vibrated radially to the grinding wheel by means of an ultrasonic transducer at amplitudes up to approximately 0.001 in. and at frequencies ranging between 10 and 18 kcps. Significant desirable effects include better surface finish of the workpiece, lower surface temperature, reduction of residual stress and, consequently, less danger of cracking. On the other hand, grinding under such vibrating conditions results in a lower grinding ratio, i.e., more rapid wheel wear. It is anticipated that commercial applications of certain grinding operations could be made immediately with little development effort.

While the results reported are preliminary in nature, with very little analysis given, reviewer believes that this paper opens up a new and potentially useful field for further detailed study.

B. T. Chao, USA

3262. **Kliever, W. H., Automatic machining—a view and a preview. Part I,** *Control Engng.* **2,** 9, 112–126, Sept. 1955.

3263. **Kliever, W. H., Automatic machining—a view and a preview. Part II, Ways to measure position and size,** *Control Engng.* **2,** 10, 84–89, Oct. 1955.

3264. **Kliever, W. H., Automatic machining—a view and a preview. Part III, Ways to measure position and size,** *Control Engng.* **2,** 11, 77–93, Nov. 1955.

3265. **Peszkowski, S., Measurement of surface finish by the method of pneumatic integration** (in German), *Feingerätetech.* **3,** 7, 299–304, July 1954.

Hydraulics; Cavitation; Transport

(See also Revs. 3237, 3288, 3300, 3302, 3347, 3358, 3444, 3453)

3266. **Ehrich, F. F., Some hydrodynamic aspects of valves,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-114, 7 pp. + 13 figs.

Free-streamline potential-flow analysis is used to analyze the flow regulation in two-dimensional valve configurations. Experimental data are reported which evaluate the accuracy of some of the derived expressions and also evaluate the possibility of applying the results to three-dimensional, axisymmetric configurations. An analysis is also carried out to evaluate the dynamic forces on the moving element of a flapper valve resulting from the motion of the fluid. Equivalent spring force and damping force are detected as well as some unstabilizing influences of negative damping and negative apparent mass.

From author's summary by H. A. Einstein, USA

3267. **Daily, J. W. and Johnson, V. E., Jr., Turbulence and boundary-layer effects on cavitation inception from gas nuclei,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-142, 14 pp. + 10 figs.

Recent researches on the inception of cavitation in a liquid medium point to the conclusion that the usual cavitation parameter K_i is inadequate as a scaling law. This statement is confirmed by the investigation at the MIT Hydrodynamics Laboratory carried out by authors, using a small water tunnel with controlled air content. In this way an essentially two-dimensional flow was investigated of water containing a dispersion of gas bubbles as nuclei for cavitation. A great number of high-speed motion picture frames were taken of cavitation near the minimum pressure region and upstream of this zone. As a conclusion to their observations, authors state that cavitation starts gas bubbles in the fluid; these bubbles will become unstable at a pressure less than the vapor pressure by an amount depending on the nuclei size. Only if relatively large gas nuclei are present, does incipient cavitation occur when K_i is attained, that is, at or near the vapor pressure. Authors state also that cavitation is incipient near the center of the turbulent boundary layer as a result of large vortical eddies which pull gas nuclei

to their centers. They are of opinion that the main source of macroscopic gas nuclei is the hydrophobic boundary material; the undissolved gas volumes, trapped in its crevices, will grow at sufficiently low pressures to be swept away as small gas bubbles by the passing flow. Dissolved-gas content should have little or no effect on K_i for small bodies with steep pressure gradients tested at high velocities. Following these lines, a new formula for the incipient cavitation index K_i is presented, as a sum of a minimum pressure-drop coefficient, a pressure-drop coefficient due to turbulence, and a pressure coefficient containing the effect of gas-nuclei size. A. Ghetti, Italy

3268. Matthews, C. S., and Lefkovits, H. C., Studies on pressure distribution in bounded reservoirs at steady state, *J. Petr. Technol.* **7,** 11, 182–189, Nov. 1955.

In an earlier paper [*Trans. AIME* **201,** p. 182, 1954; T. P. 3876] by first author and others, a method for determining average pressures of drainage areas in a bounded reservoir was presented; but actual irregular areas had been replaced by symmetric areas. A question of accuracy remained.

This paper investigates the accuracy through two attacks. First, Southwell's relaxation method is applied. Second, a model, consisting of ingenious adaptations of sandbed fluid mapper techniques, showed actual areas, and analyses of the flow patterns gave a check on the relaxation results.

The accuracy of the method of T. P. 3876 is found good enough to merit use with some confidence. Suggestions are given for estimation of drainage areas and for squaring-up of the areas.
A. D. Moore, USA

3269. Yagodin, N. N., Silting before dams and operation of power plants (in Russian), *Gidrotekh. Stroit.* **24,** 8, 25–28, 1955.

3270. Smolyaninov, N. T., Local scour in the tailwater (in Russian), *Gidrotekh. Stroit.* **24,** 8, 32–34, 1955.

Several inconsistencies of the Vyzgo method [AMR **8,** Rev. 1711] are demonstrated. Author offers his own method, based on the relationship between the bottom velocity and admissible velocity for 1-m depth, corrected by a factor for influence of stream pulsation in exponential form. Rules for use of this method are described.
S. Kolupaila, USA

3271. Gratsyanskiĭ, M. N., Wave action on overflow dams (in Russian), *Gidrotekh. Stroit.* **24,** 7, 31–35, 1955.

Measurements were made on a 1/50 scale model of the Kuybitschev dam for the influence of traveling waves upstream of the dam. The shape and velocity of these waves are argued to be constant, the transport over the dams is shown to change only by the change of water level upstream, the flow velocity is not changed. If the wave amplitude is of the same order as the water height above the dam, the transport over the dam for rising wave is greatly different from that for falling wave. Semi-empirical formulas are given (from experiments) for transport in presence of waves (dimensionless by transport without waves) expressed in water-wave height upstream of the dam, neglecting kinetic energy. Mean coefficient of transport checks well with experiments. From the transport, water height downstream of the dam can be calculated by Bernoulli's law and the momentum equation.

It is recommended to take account of the effects of these wind-generated waves upstream and to compare them with model experiments in the construction of new dams.
R. Timman, Holland

3272. Dadabaiev, K. B., Means for protection against scour in tailwater (in Russian), *Gidrotekh. Stroit.* **24,** 7, 40–42, 1955.

Description is given of a spillway of 600m³/sec capacity, 432-m length and 17-m difference between the headwater and tailwater elevation. High speeds and whirlpools of a high water of 395m³/sec have caused scouring and destruction of the apron in a length of 64 m. A subsequent model test showed full agreement between the effects in nature and in laboratory. Thus it was possible to design with confidence the reconstruction works on basis of further model tests. One row of baffles in the parabolic downstream face of the spillway and four dividing walls on the apron assured the submergence of the hydraulic jump and the prevention of the whirl pool. In addition, an 8-m deep cut-off wall at the end sill was recommended as well as the protection of the banks to a length of 40 m behind it. [See also AMR **8,** Rev. 1711.]
L. Suklje, Yugoslavia

3273. Kartvelishvili, N. A., Stability in general in stationary regime of water-power plants with equalizing reservoirs (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **20,** 25-30, 1954.

3274. Karadzhi, K. M., Computation of the cover of hydraulic gates (in Russian), *Gidrotekh. Stroit.* **22,** 11, 32–34, 1953.

Incompressible Flow: Laminar; Viscous

(See also Revs. 3193, 3250, 3266, 3268, 3299, 3303, 3304, 3308, 3311, 3314, 3319, 3320, 3332, 3341, 3343, 3358, 3391, 3393, 3403, 3404, 3421, 3444, 3445, 3447, 3448, 3450)

3275. Bazer, J., and Karp, S. N., On a steady-state potential flow through a conical pipe with a circular aperture, *J. rational Mech. Analysis* **5,** 2, 277–322, 1956.

Incompressible inviscid flow through a truncated circular cone extending to infinity is considered. It is assumed that the only singularity is a source at infinity inside the cone and a sink of equal strength outside the cone also at infinity. The solution of the Laplace equation with the adequate boundary conditions is obtained in form of integrals of infinite products of Legendre functions. Related functions and the necessary transformations are discussed on 30 pages. Finally, a uniqueness proof of the solution is given.

Reviewer can conceive that the discussions could be of interest if new mathematical methods or transformations have been used; this could not be verified. The uniqueness proof is unnecessary since the uniqueness proof of the Laplace equation in a simply connected region is given in text books (for instance "Methoden der Math. Physik" Courant, R., and Hilbert, D., 2nd ed., 1937, Vol. I, p. 274 ff). The solutions are of little interest in fluid flow since fluid flow does not behave that way in the region of interest, namely near the aperture of the cone. However, the solutions might apply to other physical phenomena such as flow of electricity.
H. P. Eichenberger, USA

3276. Martinek, J., Yeh, G. C. K., and Zorn, H. C., Theoretical studies of wake and thrust deduction. A contribution to potential theory in three dimensions, Reed Res. Inc., Washington, D. C., Proj. RR 815 B, Final Rep. 11, [David W. Taylor Mod. Basin Cont. No. 1445(00)], 157 pp., June 1955.

The studies leading to this report were performed to provide a mathematical basis that will enable naval architects to estimate the interaction between a propeller and a ship. In this report the ship is represented by a sphere and the propeller is represented by singularities outside the sphere. Thus the problem reduces to the following situation: given the potential due to a distribution of singularities outside a spherical region of radius α, find the potential caused by the image system corresponding to these singularities such that the normal derivative of the potential is zero on the surface of a sphere of radius α. The solution for this problem is given by the Weiss exterior sphere theorem which may be considered a generalization of the Milne-Thomson circle theorem. In

some cases it is more convenient to treat the inverse problem, and chap. I of this report contains a proof for the "interior sphere theorem," i.e., given a potential of a total mass zero lying inside a sphere of radius α, find the distribution of images outside the sphere such that the normal derivative is zero on the sphere.

In chaps. II and III, a number of specific examples are calculated in detail, and in chaps. IV and V, the interaction between the sphere and the singularities is derived for a number of "classical propellers."

In chap. VI, a general sphere theorem is proved, which contains within it the Weiss theorem and the "interior theorem" proved in chap. I, for mixed (linear) boundary conditions.

Chapter VII contains an extension of the sphere theorem to the case of concentric spheres for both Dirichlet and Neumann boundary conditions.

Finally, chap. VIII contains a calculation for the interference between a prolate spheroid and a propeller by means of Lagally's theorem and expansions in spheroidal coordinates.

Reviewer believes that the importance of this report lies in the increased understanding of the interaction problem. The "interior theorem" will be most useful when the image system can be identified with a physical wake system. E. E. Covert, USA

3277. Grogan, G. C., Low-wave-drag bodies of revolution as determined by linearized theory, *J. aero. Sci.* **23**, 6, p. 612 (Readers' Forum), June 1956.

H. M. Parker has presented a linearized method of determining minimum-wave-drag ducted bodies of revolution. This note is submitted to demonstrate how Parker's method of satisfying the boundary conditions may be extended to include a larger class of body shapes with arbitrary body radius control points.

From author's summary

3278. Hinze, J. O., Fundamentals of the hydrodynamic mechanism of splitting in dispersion processes, *AICHE Journal* **1**, 3, 289-295, Sept. 1955.

The splitting of globules is an important phenomenon during the final stages of disintegration processes. Three basic types of deformation of globules and six types of flow patterns causing them are distinguished.

The forces controlling deformation and breakup comprise two dimensionless groups: a Weber group, and a viscosity group. Breakup occurs when the Weber number exceeds a critical value. Three cases are studied in greater detail: (a) Taylor's experiments on the breakup of a drop in simple types of viscous flow: (b) breakup of a drop in an air stream: (c) emulsification in a turbulent flow.

It is shown that the critical value of the Weber group depends on the type of deformation and on the flow pattern around the globule. The interrelationship between the three cases and the value of the Weber group is investigated. A formula is derived for the maximum drop size. K. J. DeJuhasz, Germany

Compressible Flow, Gas Dynamics

(See also Revs. 3311, 3318, 3321, 3323, 3332, 3334, 3338, 3349, 3355, 3393, 3446)

3279. Berker, R., On the compatability equations related to a moving gas (in French), *C. R. Acad. Sci. Paris* **242**, 3, 342-344, Jan. 1956.

Generally, problems in fluid mechanics are stated in terms of given boundary equations and a state equation and the velocity field is sought. In some circumstances the indirect approach is equally acceptable; that is, given a suitable velocity distribution, find the boundary conditions and state equations. An example of this procedure is the Karman-Tsien compressibility correction for incompressible pressure coefficients. In the present paper the set of equations containing only the external force field and the velocity field are derived which constitute the necessary and sufficient conditions for the velocity distribution in an inviscid, nonconducting gas. Given a velocity distribution which satisfies these compatibility equations, the pressure and density distribution are found by quadrature and the equation of state follows as the solution of a first-order differential equation.

This work generalizes the results of Munk and Prim, and of Hicks, Guenther and Wasserman, since these more complete compatability equations are valid for the nonsteady flow within an arbitrary external force field with no assumptions made as to the nature of the equation of state.

There appears to be a typographical error in the first term on the left hand side of Eq. (7) which should be a derivative with respect to the density rather than the pressure.

E. E. Covert, USA

3280. Hall, M. G., The accuracy of the method of characteristics, *Aero. Res. Labs., Melbourne, Austral. Rep.* A. 95, 28 pp. + 3 figs., Sept. 1955.

The characteristics computation for two-dimensional supersonic flow is studied. The mechanism of error propagation is analyzed. This is followed by a determination of the effects, on the results of the computation, of the various types of error introduced in its course. The theory can be employed to plan computations in advance for achieving a specified accuracy with minimum labor.

From author's summary by T. Riabokin, USA

3281. Verschaffelt, J. E., On the flow relative to a fluid (in French), *Bull. Acad. roy. Belgique Cl. Sci. (5)* **41**, 10, 1106-1112, 1955.

Author demonstrates that, in relative coordinates, temperature is a mass-attached (extensive) property, and pressure is an intensive property for nonviscous, non-heat-conducting fluids. He also comments on the apparent differences in the equations of motion when specific volume is used instead of density.

W. Daskin, USA

3282. Tarapov, I. E., Solution of a problem for the motion of viscous gas between two moving parallel plates showing heat emission (in Russian), *Prikl. Mat. Mekh.* **19**, 3, 325-330, 1955.

The problem presents a contribution to the theory of compressed-gas lubrication. Cases investigated mathematically: where one plate is thermaliy insulated, the other being at constant temperature, and where constant temperatures are maintained on both plates. For subsonic velocities, distribution of velocity $v(y)$ and temperature are found. The nondimensional frictional stress $\tau\delta/\mu_0 v_0$ can become less than the corresponding value for a noncompressible fluid only in the case of constant temperatures maintained on both plates. For considered conditions, $v(y)$ differs only slightly from linear function which corresponds to a noncompressible fluid with constant viscosity.

P. Bielkowicz, USA

3283. Fraenkel, L. E., The theoretical wave drag of some bodies of revolution, *Aero. Res. Counc. Lond. Rep. Mem.* 2842, 26 pp., 1955.

This report investigates the wave drag of bodies of revolution with pointed or open-nose forebodies and pointed or truncated afterbodies. The "quasi-cylinder" and "slender-body" theories are reviewed, a reversibility theorem is established, and the concept of the interference effect of a forebody on an afterbody is introduced.

The theories are applied to bodies whose profiles are either straight or parabolic arcs, formulas and curves being given for forebody and afterbody drag, and for the interference drag. The re-

sults of the two theories are compared and are seen to agree well in the region of geometries where both theories are applicable.

From author's summary by J. DeYoung, USA

3284. Woods, L. C., Aerofoil design in two-dimensional subsonic compressible flow, *Aero. Res. Counc. Lond. Rep. Mem.* 2845, 54 pp., 1955.

This report is the newest of several that deal with methods for calculating the aerodynamic characteristics of given airfoils and the opposite problem of finding the coordinates for a given velocity distribution. The original results [Lighthill, *R&M* 2112] required an analytic description of the velocity distribution. Later, a technique was devised [Glauert, *R&M* 2683] for using a stepwise analytic description. In the present report, a method is presented that enables the designer to compute, by elementary processes, the ordinates if the velocity distribution is given in tabulated form, and conversely. The effects of compressibility are based on an approximation that is similar to the Karman-Tsien method.

Reviewer is of the opinion that Dr. Woods' method is practical. The application of this technique enables the designer to not only calculate the ordinates corresponding to the velocity distribution, but also to estimate the effects of profile modification upon the velocity distribution.

E. E. Covert, USA

3285. Kusukawa, K.-I., The application of Meksyn-Imai's method to the subsonic flow past an axisymmetric body, *J. phys. Soc. Japan* **10,** 12, 1088–1092, Dec. 1955.

Meksyn [AMR **7,** Rev. 2907] analyzed plane subsonic flow by adopting incompressible streamlines and potential lines as coordinates, approximating resulting equation, and iterating on incompressible solution. Result is quintic equation for surface speed, whose coefficients depend on shape of obstacle. Imai (unpublished) pointed out coefficients can be related to those in first three terms of Janzen-Rayleigh expansion in powers of M^2. Hence method is a reinterpretation of Janzen-Rayleigh series that apparently speeds convergence. Present paper gives entirely parallel treatment of axisymmetric flow, with identical results. Sphere is treated as example.

M. D. Van Dyke, USA

3286. Kusukawa, K.-I., On the subsonic flow of a compressible fluid past an axisymmetric moderately thick body, *J. phys. Soc. Japan* **10,** 12, 1093–1101, Dec. 1955.

Previously, using hodograph transformation and various approximations, author related subsonic and incompressible flows past same slender axisymmetric body [AMR **8,** Rev. 2348]. Using that as a basis, he now develops a refined approximation by similar means. The related incompressible flow is that past a slightly distorted body. Corresponding treatment of plane flow was given by Imai [AMR **3,** Rev. 2725; **5,** Rev. 809] and function tabulated there recurs here. For prolate spheroids, numerical comparison of surface speed is made with linear, Janzen-Rayleigh, and Meksyn-Imai approximations (see preceding review). Although essential nature of approximation is not evident to reviewer, it apparently yields reasonable results for fairly thick bodies.

M. D. Van Dyke, USA

3287. Spreiter, J. R., On the range of applicability of the transonic area rule, *NACA TN* 3673, 21 pp., May 1956.

Transonic drag data available from bump tests in the Ames 16-ft high-speed wind tunnel for a large family of rectangular wings having NACA 63A xxx section, aspect ratios varying from 0.5 to 6.0, thickness ratios from 2 to 10%, and both symmetrical and cambered profiles [see *NACA TN* 3501 and 3502], are used to examine in detail the applicability of the transonic area rule. According to this rule the increase $\Delta(D_0/q)$ in the ratio of zero-lift drag D_0 and dynamic pressure q between a subcritical Mach number and a transonic Mach number M_0 is a function of M_0 and the cross-sectional area distribution of the configuration in question. For the chosen wing family this area distribution is completely described by $(S_m/c^2)s(x/c)$, where $s(x/c)$ is a fixed distribution function (defined by the geometry of the profile series) and where S_m/c^2 is the ratio of maximal cross section area S_m to the square c^2 of the body length. Clearly $S_m/c^2 = A\tau$ (A aspect ratio, τ relative thickness), the area rule for the given wing family thus taking the form

$$\Delta(D_0/qc^2) = f(M_0, A\tau) = (S_m/c^2)^2 f_1(M_0, A\tau) \quad [1]$$

Transonic similarity rules as given in *NACA TR* 1153 reformulated for the present case and applied to the wave drag D_{0w} for $M_0 = 1$ may be written in the form

$$D_{0w}/qc^2 = (S_m/c^2)^2 f_2(A\tau^{1/3}) \quad [2]$$

With regard to wings having identical area distributions, the test results for two symmetrical wings ($A\tau = 2 \times 0.08 = 4 \times 0.04$) show sufficiently good agreement with [1], $f_1(M_0, 0.16)$ being nearly the same function of M_0 for both wings. Results for three differently cambered wings ($A = 2$, $\tau = 0.06$ for all wings), however, show considerable disagreement, revealing the fact that addition of camber strongly increases the sonic drag rise. With regard to wings having only similar area distributions, the test results for all the uncambered wings and for $M_0 = 1$, when plotted as $\Delta(D_0/qc^2)$ vs. $(S_m/c^2)^2$, fall near a single straight line through the origin for all aspect ratios up to 3, which is in accordance with the area rule, but for wings of higher aspect ratios they depart from this line in a systematic manner.

[1] and [2] are compatible only if $f_1(1, A\tau)$ and $f_2(A\tau^{1/3})$ are constant for small values of $A\tau^{1/3}$. For symmetrical wings and for $A\tau^{1/3}$ less than about unity this fact is well demonstrated by the tests: within this range the sonic drag rise varies as the square of the maximum cross-section area, all wings having equal chords.

H. Behrbohm, Sweden

3288. Bryant, R. A. A., The hydraulic analogy as a distorted dissimilar model, *J. aero. Sci.* **23,** 3, 282–283 (Readers' Forum), Mar. 1956.

By use of the hydraulic analogy, author investigates transonic flow over a two-dimensional thin wedge, treating the physical water flow around the wedge profile as a distorted dissimilar model of a corresponding prototype gas flow about the same profile. Transonic similarity rule is employed. The distortion of the profile due to the existence of boundary layer is taken into account.

S. Tomotika, Japan

3289. Holt, Maurice, Progress in research on high speed flow. Part 1, Normal supersonic flow; Part 2, Transonic flow; Part 3, Hypersonic flow; *Aircr. Engng.* **27,** 321, 371–373, Nov. 1955; **27,** 322, 392–395, Dec. 1955; **28,** 323, 21–24, Jan. 1956.

Excellent brief review of some fairly recent work and problems still remaining in supersonic flow about yawed bodies of revolution, transonic flow about arbitrary profiles, hypersonic flow approximations, the hypersonic viscous flow over a flat plate, and some of the experimental techniques connected with these problems.

Reviewer would like to point out recent developments since this publication. Holt himself has a paper in a forthcoming *Journal of Fluid Mechanics* which gives a more exact method for flow about yawed bodies of revolution. Holt has generalized the work of Coburn and Dolph [AMR **3,** Rev. 1523] to include the variable entropy and vorticity occuring behind all curved shock waves. Coburn and Dolph were the first to point out that meridian planes through the axis of symmetry of an inclined body of revolution cannot contain the bicharacteristic direction so that any finite-difference solution based on such a coordinate system would be an approximation valid only for small angles.

Mackie and Pack [AMR **8,** Rev. 2451] have contributed to the study of transonic flow over a wedge at high subsonic Mach num-

bers and point out that the problem of flow behind shoulder is still unsolved. E. V. Laitone, USA

3290. Hammitt, A. G., and Bogdonoff, S. M., Hypersonic studies of the leading edge effect on the flow over a flat plate, *Jet Propulsion* **26,** 4, 241–246, 250, Apr. 1956.

Using the Princeton helium hypersonic wind tunnel, study was carried out by optical measurements of shock position over a wide range of leading-edge thicknesses and surface pressure measurements for the thicker leading edges. The flow over the plate with a thick leading edge was found to be essentially inviscid, but viscosity was important for the case of thin leading edges. This is shown by a series of interferograms taken at $M = 12.7$. The magnitude and downstream persistence of the thick-leading-edge effects on the shock shape and surface pressure distribution is surprising. Authors give a qualitative explanation of this fact based on the reflection of the expansion waves starting at the leading edge, both on the sonic line and on the detached shock front. Since a 90° Prandtl-Meyer expansion gives infinite Mach number for helium, reviewer believes that the corresponding effects of the thick leading edges would be somewhat reduced in air.

P. Schwaar, France

3291. Tsien, S. H., The supersonic conical wing of minimum drag, *J. aero. Sci.* **22,** 12, 805–817, 843, Dec. 1955.

See AMR **7,** Rev. 1186.

3292. Licher, R. M., Drag due to lift in supersonic flight for circular planform wing with an arbitrary radial distribution of lift, *Douglas Aircr. Co. Rep.* SM-19119, 12 pp., June 1955.

A method given by Graham for obtaining the drag of superimposed optimum lift distributions in supersonic flight is extended and applied to the case of a circular planform wing.

A. R. Mitchell, Scotland

3293. Howard, L. N., and Matthews, D. L., On the vortices produced in shock diffraction, *J. appl. Phys.* **27,** 3, 223–231, Mar. 1956.

The vortex produced by a weak shock passing over a 5° vertical wedge has been studied experimentally and theoretically. The density in the vortex was observed interferometrically. The initial pressure was varied from 300 to 800 torr and the time of taking the picture from 80 to 800 μsec. Single fringe interferograms and shadowgrams show a well-developed radial-symmetrical distribution of density and a spiral slip stream winding off the corner which contains small secondary eddies. The average angular spacing of these eddies, measured from the vortex center, appears to be independent of shock strength and time.

The theoretical considerations are based on the compressible flow equations with the following additional critically discussed properties: (a) no discontinuities (slip streams, shocks), (b) no viscosity and heat conductivity, (c) isentropic flow, (d) pseudostationary flow (uniform expansion in time), (e) radial symmetrical flow (symmetry about the origin). On the additional assumption that only the radial component of the centrifugal force on a particle of fluid be considered, the equations of flow can be reduced to a single ordinary nonlinear differential equation.

The main parameters in the theory are the rate of growth of the vortex and a quantity which is called "strength of the vortex." By fitting essentially one parameter of the theory to the observed density, good agreement is obtained over the region of the vortex, except at the very center. The theory does not consider the formation of the vortex.

The rate of growth of the vortex as a function of free-stream Mach number has been found to agree with a result based on another theory of N. Rott (private communication).

H. Schardin, Germany

3294. Kogan, A., On supersonic rotational flow behind strong shock waves, I. Flow past airfoils, *AF tech. note* AFOSR-TN-56-165, 53 pp. + 4 figs., 1956.

A method of successive approximations to the inviscid rotational flow past airfoils at high supersonic Mach numbers is developed. The uniform flow behind a plane shock wave is the zero-order approximation. First and second derivatives of $C_p(x)$ on the airfoil surface, and the shock curvature and its derivative are calculated in terms of the airfoil curvature and its derivative at the leading edge. S. A. Schaaf, USA

3295. Broglio, L., Method of integration for supersonic flow behind an attached shock wave, Università di Roma, Scuola di Ingegneria Aeronautica, Rome, *SIARgraph* no. 3, 114 pp., Mar. 1955.

For supersonic flow past a pointed body with attached shock, knowledge of the field near the apex facilitates its computation elsewhere by the method of characteristics. Author proposes use of higher-order corrections to conical flow for treatment of bodies with curved meridian sections. With apex as origin of spherical polars r, η, ω, dependent variables are corresponding velocity components u, v, w, and specific entropy S. He assumes existence of r-derivatives of all orders of u, v, w, S at $r = 0$, hence repeated differentiation of governing equations yields linear "higher-order conical flow equations" at $r = 0$ for $(\partial^n u/\partial r^n)_{r=0}$, etc. The differentiated equations give usual nonlinear conical flow equations at $r = 0$. All applications are quasi-axisymmetric fields for which w and the ω-derivatives are small. The first- and second-order equations are given explicitly for isentropic flow. For numerical integration of equations of cone-field type, author proposes a method more elaborate than usual but apparently much faster, and tests it for symmetric cones. Numerical applications are to cones at small yaw and unyawed RM 10 body of revolution. Reviewer notes no estimate of order of magnitude of higher-order cone field terms so that rapidity of convergence of power series in r for dependent variables is unknown. Thus the extra work to obtain first few higher-order fields may not be worthwhile when compared with linearized method of characteristics based on zero-order cone field [AMR **5,** Rev. 1137].

H. C. Levey, Australia

3296. Gadd, G. E., A simple theory for interactions between shock waves and entirely laminar boundary layers, *J. aero. Sci.* **23,** 3, 225–230, Mar. 1956.

Author assumes an approximate formula for the velocity profiles of the laminar boundary layer and applies this to the two-dimensional interaction of the layer with shock waves generated by a wedge or by compression waves. He assumes further that the boundary layer remains laminar and that the shape of the outer part of the velocity profiles does not alter throughout the interaction region. The method consists in the combination of two expressions for the pressure gradient into a differential equation, which is solved numerically: (a) at the wall the rate of change of friction stress normal to the wall is equal to the pressure gradient and (b) the relation between pressure and the deflection of the external flow created by the growth of the boundary layer. The theoretical results are compared with experiments in great detail, and show a fair agreement. K. Pohlhausen, USA

3297. Sagomonian, A. Ya., Shock wave reflection from a solid wedge (in Russian), *Vestnik Moskov. Univ., Ser. Fiz.-Mat. Estest. Nauk* (1) **10,** 2, 33–40, Feb. 1955.

A shock wave of arbitrary shape is incident on a blunt wedge. The flow parameters behind the reflected wave are found for the case of regular reflection. The pressure on the wedge in the region influenced by its vertex is estimated by assuming that the stagnation point, at this point, is connected by a one-dimensional simple wave, running along the wedge surface, to the higher pressure region behind the reflected wave.

R. Hetherington, England

3298. Eckhaus, W., On the theory of shock reflection on walls with slots, *Nat. LuchtLab. Amsterdam Rap.* F. 167, 20 pp., 1955.

First sections of report, which gives a theory of transonic wind tunnels, give second-order approximations for reflection of shocks against solid and open boundaries (contact discontinuities) and interaction between shocks and Prandtl-Meyer waves. For walls with transversal slot, a shock hitting the boundary originates a series of successive expansion and compression waves, at the edges of the solid parts of the wall. At large distance from wall, disturbances are cancelled through interaction of each expansion wave with preceding and succeeding shock waves. Instead of interaction theory, a simplified calculation is used, based on conservation of mass, to find condition for complete cancellation. It appears that the ratio R of open to total wall area is only slightly above 0.5.

For longitudinal slots, problem is more complicated. A shock hitting the solid strip between two slots gives (as for a rectangular wing in supersonic flow) two conical shocks in the adjacent open slots, which interact with the expansion wave in this slot. Tentatively, it is assumed that, for complete cancellation, the total strength of the initial pressure disturbances at the wall behind the reflected shocks and expansion waves must be zero. This again yields a value of R of about 0.5, but in the region $1.1 < M < 1.5$ it is largely dependent on Mach number and angle of incidence of the shock.

Author states that further investigations are needed.

R. Timman, Holland

Wave Motion in Fluids

(See also Revs. 3183, 3271)

3299. Ainsworth F. W., The effect of oil-column acoustic resonance on hydraulic valve "squeal", *Trans. ASME* **78,** 4, 773-778, May 1956.

The interaction of hydraulic column, in the supply line, and the valve spool is seen by the author as a major factor of valve instability in hydraulic control systems. Two transfer functions (change in valve flow and change in valve displacement) are derived in order to apply the Nyquist stability criterion to the closed-loop system. Experimental stability tests confirmed analytical results. Methods of inhibiting valve "squeal" are given by the author. The discussors of the paper refer to another method by F. D. Eziekel.

See the work by S. Y. Lee on fluid flow forces [AMR **6,** Revs. 527, 1068].

Z. W. Dybczak, Canada

3300. Markey, M. F., Effect of carriage mass upon the loads and motions of a prismatic body during hydrodynamic impact, *NACA TN* 3619, 45 pp., Mar. 1956.

Under certain experimental conditions it is necessary to include the effect of towing-carriage mass in the analysis of hydrodynamic impact of prismatic bodies. This effect is particularly important at high trim angles. General expressions applicable to any prismatic body are obtained for the loads and motions during impact. Curves are presented to show conditions at which the carriage-mass effect is important.

G. V. R. Rao, USA

3301. Becker, E., Pulsating source under a free surface of a stream of finite depth (in German), *Ing.-Arch.* **24,** 2, 69-76, 1956.

Asymptotic forms of wave trains issuing from source are studied in plane geometry. Importance of problem arises from interest in surface disturbances from pulsating body moving under the surface.

Velocity potential is split into three parts—free waves, source term, and boundary-condition term—following general lines of Lamb.

If stream speed and pulsating frequency are not too high, four wave trains appear, one propagating upstream; otherwise there are only two, both downstream.

Writer mentions various special cases: stationary stream, pulsation frequency tending to zero, and bottomless stream, some of which have been studied before. Likely effects of surface tension are also mentioned.

Reviewer's only criticism of interesting paper is that Figs. 2 and 7 would be made simpler and clearer by omitting curves $V \pm \nu\lambda$ and drawing straight lines with slope $\pm \nu$ through points $(0, \pm C)$ to cut curve V.

A. H. Armstrong, England

3302. Andronov, A. A., and Aronovich, G. V., Theory of hydraulic rams (in Russian), *Inzbener. Sbornik, Akad. Nauk SSSR* **20,** 3-12, 1954.

3303. Hunt, J. N., On the solitary wave of finite amplitude (English and French), *Houille blanche* **10,** 2, 197-203, Mar./Apr. 1955.

It is shown that the equation to the profile of the solitary wave and the velocity of propagation can be obtained by a convenient process of successive approximation without determining the velocity potential throughout the plane of flow. The method employs an operational form of the free surface condition given by Levi-Civita (1911). The wave profile and velocity are found to the third order in the ratio a/h, a being the wave amplitude and h the undisturbed depth. For small values of this ratio the solution reduces to that of Boussinesq. The velocity equation is in good agreement with measurements reported by Daily and Stephan (1953). [See AMR **8,** Rev. 1736].

From author's summary

Turbulence, Boundary Layer, etc.

(See also Revs. 3296, 3360, 3366, 3367, 3390, 3391, 3395, 3398, 3401, 3403, 3414, 3455, 3456)

3304. Squire, H. B., Note on the motion inside a region of recirculation (cavity flow), *J. roy. aero. Soc.* **60,** 543, 203-205, Mar. 1956.

Author discusses flow in cavities under the boundary layer of the main stream on a rough surface. Using some ideas from Batchelor's papers on free convection, he suggests treating this motion as a "core" with constant vorticity surrounded by a boundary layer. To illustrate this idea, author calculates the non-turbulent flow inside a circular cylinder for which half the circumference is fixed and the other half moves tangentially with constant velocity.

J. Polášek, Czechoslovakia

3305. Rheinboldt, W., Calculation of stationary boundary layer with continuous suction and with discontinuous suction velocity (in German), *J. rational Mech. Analysis* **5,** 3, 539-604, 1956.

The two-dimensional laminar boundary-layer equations are treated with arbitrary distribution of suction. In contrast to other papers in which the assumption of the continuity of the suction velocity is essential, author discusses discontinuities in the distribution of the suction velocity, the beginning and the end of suction. Developments in infinite series are used for velocity components, these series being convergent in the neighborhood of the point of discontinuity; outside of the convergent interval of these series, any method for calculation of laminar boundary layer with continuous velocity of suction can be used. The general mathematical treatment leads to equations for confluent hypergeometric functions, and author has worked out the solution in a form suitable for numerical computation. Several examples are evaluated to illustrate the procedure.

J. Polášek, Czechoslovakia

3306. Loitsianskii, L. G., Boundary layer, *NACA TM* 1400, 29 pp., May 1956.

Translation of "Pogranichnyi sloi," from the book on "Mechanics in USSR Over 30 years, 1917-1947.

3307. Hool, J. N., Empirical relationships for local coefficients of skin friction in sub-sonic air streams, *Aero. Res. Labs., Melbourne, Austral. Aero Note* 145, 11 pp. + 13 figs., June 1955.

Some of the better known skin-friction equations are compared with experimental results found in turbulent two-dimensional subsonic air flow under a rising pressure gradient. It is found that empirical equations based on flat-plate conditions give values of local coefficients of skin friction considerably greater than the measured values. The recent equation of Ludwieg and Tillmann is substantially in agreement with the measured values.

The effect of heat transfer on skin friction under a rising pressure gradient is also considered. It is determined experimentally that heat transfer has a negligible effect on the local coefficients of skin friction in the turbulent boundary layers.

Author uses surface-tube technique (see following review) and small pitot tubes, details of which are given. The rising pressure gradient was obtained in a 4° divergent two-dimensional diffuser.

Reviewer emphasizes practical importance of observed reduction (approximately $\frac{2}{3}$) of skin friction, estimated from velocity profiles. Extensive applications are possible in hydraulics, aerodynamics, etc. A systematic study of this phenomenon is suggested. (See also E. S. Goldstein, "Modern developments in fluid dynamics," Vol. II, Oxford Univ. Press, p. 375.) A number of bibliographical references are given.

N. Krivoshein, Argentina

3308. Hool, J. N., Measurement of skin friction using surface tubes, *Aero. Res. Labs., Melbourne, Austral. Aero Note* 144, 10 pp. + 6 figs., June 1955.

Author reports about his experiments with surface tubes for measuring skin friction. His technique differs from T. E. Stanton's and from A. Fage and V. M. Falkner's in construction of surface tubes made of a segment ($\frac{1}{8}$ in. wide × $\frac{3}{16}$ in. long) of a thin razor blade soldered to studied surface. A device for calibration "in situ" is described, consisting of a flat ($2\frac{1}{8}$ in. × 0.030 in.) half-channel sealed to the surface, in which laminar current is generated by suction. Once calibrated, a surface tube provides all data for skin-friction calculation, author states.

Author then develops correction formulas for temperature density and viscosity changes, checking them by measurements [see preceding review].

Author measured the openings of his surface tubes (with a Fage and Falkner microscope) and could check his calibration data against the known curve for "effective openings" by G. I. Taylor. *All* author's points are *above* the curve; he uses them to establish a new approximate formula for skin-friction determination by means of measured openings of surface tubes.

Some of the points by T. E. Stanton and by A. Fage and V. M. Falkner are also above the Taylor curve, suggesting the need of further studies, reviewer believes.

N. Krivoshein, Argentina

3309. Sanyal, L., Boundary layer in a converging nozzle with a spherical surface, *Bull. Calcutta math. Soc.* **47**, 2, 65–70, June 1955.

A mathematical analysis utilizing boundary-layer equations is made for the case of a swirling liquid jet which enters tangentially a converging nozzle whose surface is spherical. The differential equations are solved employing suitable simplifying assumptions, and numerical results are tabulated. These numerical solutions show that, for given inlet and outlet radii and nozzle length, the boundary layer at the outlet of a nozzle with a spherical surface is slightly greater than is the boundary layer at the outlet of a nozzle with a conical surface. D. M. Mason, USA

3310. Shestopalov, V. P., A particular solution for the problem of diffused boundary layer in a diffusor (in Russian), *Prikl. Mat. Mekh.* **18**, 6, 753–756, 1954.

An exact solution of diffused boundary layer in a convergent diffusor is given. The concentraton and flow of diffusion are calculated from fundamental equation for concentration by utilizing velocity components given in Kotchin, Kibel and Rose's book. The thickness calculated by Nernst's theorem shows a proper value nearly equal to 2×10^{-3} cm. M. Kataoka, Japan

3311. Dryden, H. L., Recent investigations of the problem of transition, *Z. Flugwiss.* **4**, 3/4, 89–95, Mar./Apr. 1956.

This comprehensive review of the transition problem begins with an account of progress made in the understanding of the mechanics of transition and then summarizes the more significant theoretical and experimental work in the supersonic speed range. This in essence divides the paper between a discussion of incompressible and compressible flows—a division unavoidable at this stage due to the complications introduced by compressibility and the fact that data in the supersonic range are limited essentially to transition Reynolds numbers. Reviewer feels that author has unified the picture as much as presently possible by collecting available information and finding consistencies in the maze of confusing data. Particularly noteworthy is the clarification of conditions under which the stabilizing effect of cooling may be realized. One concluding remark of the author should express the reader's impression: "Although much remains to be done, one has the feeling that we are now on the right track and that progress will be more rapid." G. B. Schubauer, USA

3312. Reid, W. H., The skewness factor according to Obukhoff's transfer theory, *J. aero. Sci.* **23**, 4, 379–380 (Readers' Forum), Apr. 1956.

The behavior of skewness factor s for both large and small Reynolds numbers has been calculated. It was found that the variation of s/y with Reynolds number is small, where y is an arbitrary constant in Obukhoff's expression for the transfer function.

S. I. Pai, USA

3313. Braun, W. H., On a stress tensor for turbulence, *J. aero. Sci.* **22**, 7, 510–511, July 1955.

A new stress tensor for turbulence is proposed satisfying the conditions that (1) the formulation of the stresses must be a tensor; (2) it must be consistent with the two boundary conditions that the mean velocity should vanish at the solid boundary and should attain a maximum at some other surface; (3) the magnitude of the stress component should remain invariant while its sign undergoes a change due to reflection of a coordinate that corresponds to one of the directions associated with that component; and (4) a part of the stress tensor should represent the dissipative forces.

This formulation is applied to fully developed pipe flow and a new relation for the mean velocity near the wall is given. The mean velocity varies smoothly from the linear law in the laminar region to a nearly logarithmic curve where the turbulent stresses predominate. This formulation cannot be used to predict mean velocity profiles in flows not already experimentally investigated.

S. D. Nigam, India

3314. Phillips, O. M., The irrotational motion outside a free turbulent boundary, *Proc. Camb. phil. Soc.* **51**, part 1, 220–229, Jan. 1955.

Author considers the irrotational motion of an infinite fluid when the normal velocity across a plane is specified as a stationary random function of position in the plane, and a solution is obtained in terms of the specified boundary conditions. It is shown that the mean square velocity normal to the plane is equal to the

sum of the mean squares of the velocities in the other two orthogonal directions. The asymptotic variations with distance normal to the plane are found for functions representing the important properties of the motion, and, in particular, the energy of the fluctuations is shown to be inversely proportional to the fourth power of the distance from the plane. The conditions postulated are shown to correspond closely to the motion outside a free turbulent boundary, and good agreement is found between the predictions of the theory and the available experimental results. (*From author's summary*)

Reviewer notes that in the "Introduction" it is stated that "observations upon a cathode-ray oscillograph of a signal representing the instantaneous vorticity at a point near the outside of a turbulent wake, for example, show intermittent periods of high fluctuating vorticity dispersed among periods of zero vorticity." Such *wake* vorticity observations are apparently unpublished, and no reference is given. In the light of published information, however, such vorticity behavior is expected in the wake.

The restriction to homogeneity in planes parallel to the wake appears to require further justification for the application; if Phillips' relation among the three mean squared velocity components is substituted into an equation for the general irrotational case [Eq. (26) of Corrsin and Kistler, *NACA TN* 3133, 1954; AMR **7**, Rev. 1551], a nonzero shear results. In Phillips' approximation, the turbulent shear stress is zero.

S. Corrsin, USA

3315. Favre, A., Gaviglio, J., and Dumas, R., Turbulent boundary layer: Double space-time correlations and spectra (in French), *Rech. aéro.* no. 48, 3–14, 1955.

Detailed results are given of the authors' experiments on the structure of the boundary layer over a flat plate. Two flows are examined, one by creating turbulence throughout the stream by means of a grill and the other by roughening the leading edge in a uniform stream. Two hot wire anemometers, refinements of previous types, are used, and their influence on the flow is calculated and shown to be negligible. Graphs are given of the mean velocity profile and turbulence intensities, spectra and space-time correlations normal and parallel to the plate. Taylor's hypothesis is verified by comparing autocorrelations in two positions with the space correlation. Time delays corresponding to maximum correlation are plotted as functions of relative position and, in the case of an initially turbulent stream, contours of maximum correlation (with respect to time) for four positions of the fixed wire are given.

R. P. Pearce, Scotland

3316. Fales, E. N., A new laboratory technique for investigation of the origin of fluid turbulence, *J. Franklin Inst.* **259**, 6, 491–515, June 1955.

Paper describes an experimental technique for studying boundary-layer phenomena on a flat plate, associated with transition to turbulence. Method consists of photographing dye formations from above a flat plate moved through still water, the photographic record being subsequently analyzed. In one set of experiments turbulence is produced by a spanwise trip, and in another the boundary-layer phenomena in the case of a decelerated plate are studied. In the latter case, the photographic record reveals clearly defined columnar vortexes transverse to the flow direction in a periodic pattern. Author discusses in detail the formation and decay of these vortexes and presents data on vortex spacing as a function of plate speed before deceleration.

In reviewer's opinion, relevance of results to the problem of turbulent transition is questionable, as author does not distinguish clearly between boundary-layer separation and transition. Experiments are, however, significant in themselves, and method is to be commended for simplicity and clarity in revealing flow details.

L. M. Grossman, USA

3317. Hsu, E. Y., The measurement of local turbulent skin friction by means of surface pitot tubes, *David W. Taylor Mod. Basin Rep.* 957, 18 pp., Aug. 1955.

Paper considers the problem of evaluating wall shear stress in a turbulent boundary layer. Method used is an extension of the pitot-tube technique developed by Preston for flow in pipes in which a circular tube is placed in contact with the wall. Some analysis is given based on an exponential velocity distribution ($\frac{1}{7}$th-power law) and comparisons are made with wind-tunnel test results. These latter were conducted on the wall of the low-turbulence subsonic tunnel of the David Taylor Model Basin. Both zero and adverse pressure gradients are considered. Agreement appears to be excellent, although no comparisons are made with direct shear stress data now becoming available. Maximum air speed attained in the tests is 140 fps.

M. J. Thompson, USA

3318. Carroll, J. B., and Anderson, G. F., Boundary-layer effect on local Mach number measurements on a circular arc half profile, *J. aero. Sci.* **23**, 6, 604–605 (Readers' Forum), June 1956.

Aerodynamics of Flight; Wind Forces

(See also Revs. 3283, 3284, 3291, 3292, 3332, 3333, 3334, 3336, 3340, 3342, 3345, 3406)

3319. Weissinger, J., Aerodynamics of the annular wing. The pressure distribution of thin, almost axially symmetrical wings in subsonic flow (in German), *Forsch. Wirtschafts-und Verkehrsministeriums Nordhein-Westfalen* no. 198. 30 pp., 1955.

Original treatment of lift of inclined annular wing employed lifting-line theory for small chord-diameter ratio λ and momentum theory for large λ, omitting intermediate range. Present paper now covers entire range $0 \leq \lambda \leq \infty$ accurately by means of lifting-surface theory; hence also pressure distribution and moment for first time. Analysis allows for variable incidence around circumference, but calculations are limited to axisymmetric case.

Exact method: Wing is represented by unknown distribution of ring vortexes on cylinder, with appropriate trailing vortexes. Flow tangency condition yields two-dimensional integral equation. This is reduced to one dimension by Fourier series development and, after further simplification, solved numerically. *L-method:* Wing is represented by ring vortex at $C/4$, with trailing vortexes, and tangency condition applied at $3C/4$. Closed-form solutions are obtained, plus simpler approximation formulas.

Results: Exact coefficients of radial force, lift, moment about $C/4$, aerodynamic center, and other quantities are tabulated for $\lambda = 0.5, 1, 1.5, 2, 5$. Curves of $C_L(\lambda)/C_L(0)$ show excellent agreement of L-method with exact method. Curve of lifting-line theory [reviewer, AMR **1**, Rev. 149], also shown, agrees asymptotically for small λ, as it should. Curves of aerodynamic center location (supplemented by text) show movement from $C/4$ at $\lambda = 0$ to leading edge at $\lambda = \infty$. Induced drag is also treated.

H. S. Ribner, Canada

3320. Weissinger, J., Aerodynamics of annular wings in incompressible flow (in German), *Z. Flugwiss.* **4**, 3/4, 141–150. Mar./Apr. 1956.

This appears almost identical with paper in preceding review, with addition of comparisons with experiment. Data are credited respectively to ETH-Zurich, St. Cyr, and SNECMA-ONERA. Experimental points show very good agreement with theoretical curves of lift versus chord-diameter ratio λ, considerable discrepancies on position of aerodynamic center. Latter is attributed to effects of friction drag.

H. S. Ribner, Canada

3321. Diederich, F. W., and Zlotnick, M., Calculated spanwise lift distributions, influence functions, and influence coefficients for unswept wings in subsonic flow, *NACA Rep.* 1228, 68 pp., 1955.

See AMR **7**, Rev. 1565.

3322. Wood, R. M., and Murphy, C. H., Aerodynamic derivatives for both steady and measuring motion of slender bodies, *J. aero. Sci.* **22**, 12, 870–871 (Readers' Forum), Dec. 1955.

3323. Jones, A. L., Lamb, O. P., and Cronk, A. E., A method for predicting lift effectiveness of spoilers at subsonic speeds, *J. aero. Sci.* **23**, 4, 330–334, 376, Apr. 1956.

Evaluation of existing uncorrelated data on the effectiveness of spoilers. Authors list seven parameters (besides the Mach number) that are of importance. Initial hypothesis neglects interdependence between these parameters; further improvements take into account interdependence between aspect ratio, sweep, and span-wise location of the spoilers. Results are expressed in form of design charts. G. Guderly, USA

3324. Foa, J. V., Gail, A., and Goodman, T. R., Propulsive ducts at the tips of rotor blades, *J. aero. Sci.* **23**, 4, 381–383 (Readers' Forum), Apr. 1956.

Optimum combustion-chamber design combines minimum weight (i.e., cross-sectional contour of minimum periphery and minimum wall thickness) with maximum cross-sectional area. Neglecting flexural rigidity (wall thickness sufficiently small), authors derive parametric equations for contour of chamber in equilibrium between internal overpressure and centrifugal forces. Expression for corresponding cross-sectional area is also given. Change in shape with altitude is discussed. H. Parkus, Austria

3325. Heyson, H. H., Analysis and comparison with theory of flow-field measurements near a lifting rotor in the Langley full-scale tunnel, *NACA TN* 3691, 162 pp., Apr. 1956.

Paper gives quite detailed results of measurements of (time-averaged) normal induced velocity v in entire vicinity of a single rotor, which was of teetering type, with untapered, untwisted blades. Forward tip-speed ratios μ ranged from 0.095 to 0.232. Comparison with existing theories indicates satisfactory agreement as far rearward as 3/4 of a diameter behind leading edge of rotor disk, provided a realistic nonuniform disk loading is assumed in the theoretical calculations. Behind the 3/4 point, calculation of the induced velocity becomes inaccurate because of the rolling up of the trailing vortex system. At locations well behind the rotor, however, the induced flow can be calculated fairly accurately by assuming the rotor to be a uniformly loaded rectangular wing, provided that the rotor lift coefficient is sufficiently high. Measured induced velocity at rotor center is zero, and this is explained by the zero load carried by the rotor there.

Paper is a valuable contribution to experimental information on the induced flow near a lifting rotor. M. Morduchow, USA

3326. Ramachandra, S. M., Direct calculation of propeller deflection, *J. aero. Sci.* **22**, 10, 726–728, Oct. 1955.

A simple noniterative method for the calculation of propeller deflection is obtained by a finite difference approximation of the differential equation governing the bending of the propeller.

From author's summary

3327. Puttock, D. R., Loading conditions following an automatic pilot failure (rudder channel), *Aero. Res. Counc. Lond. curr. Pap.* 242, 7 pp. + 2 appendixes + 1 table + 7 figs., 1956.

A method is presented for the determination of the critical loading conditions of aircraft that ensue from an automatic-pilot failure in the rudder channel.

General expressions have been derived through response theory for the angle of sideslip, fin-and-rudder load, and lateral acceleration both at the c.g. of the aircraft and at the tail that result from the sequence of rudder movements assumed to follow an automatic-pilot failure. Analysis of these general expressions leads to formulas suitable for assessing the numerical values of the critical loading conditions and it is suggested that these formulas might form a basis for the interpretation of the appropriate design requirement.

An example is given to illustrate the type of response produced by a rudder-channel failure and the calculation procedure.

From author's summary

3328. Puttock, D. R., Loading conditions following an automatic pilot failure (elevator channel), *Aero. Res. Counc. Lond. curr. Pap.* 243, 10 pp. + 2 appendixes + 1 table + 10 figs., 1956.

A proposal is made for a standard procedure for calculating the critical loading conditions ensuing from an automatic-pilot failure in the elevator channel.

General expressions are derived through response theory for the increments in normal acceleration at the c.g. of the aircraft, normal acceleration at the tail, and aerodynamic load on the tailplane which result from the sequence of elevator movements assumed to follow a failure. Analysis of these general expressions leads to formulas suitable for assessing the numerical values of the critical loads on the wing and tailplane.

The influence of the sequence of elevator movements on the loading conditions is discussed with reference to an example.

From author's summary

3329. Shields, R. T., Stephenson, J., and Utting, I. E., An investigation of high altitude cruising conditions for turbo-jet aircraft, *Aero. Res. Counc. Lond. curr. Pap.* 215, 13 pp. + 1 table + 3 appendixes + 11 figs., 1956.

Specific air range has been measured on the Ashton Mk. 1 at high altitude using differing techniques. A "quasi-level" procedure consisting of runs at constant speed involving a small rate of climb or descent is recommended for performance measurements near the optimum range conditions and any speed below about M = 1.2. Optimum specific range for the Ashton is obtained at the theoretically predicted conditions for an aircraft cruising below its drag critical Mach number, i.e., maximum rpm and M = 1.2; increase of air temperature reduces this specific air range by about 1¾% per 10C. Some evidence of scale effect on specific air range during a long range flight is shown; this is likely to be more important for a long-range bomber. From handling aspects, flying manually in the optimum climb cruise conditions and at speeds down to M = 0.9 was quite practicable and comfortable, but the static margin on this aircraft even at the aft c.g. was high; it was therefore not possible to assess a minimum acceptable limit of static stability for range flying. An appendix derives and discusses the conditions for maximum specific air range, the argument being extended to the case with compressibility drag effects.

From authors' summary

3330. Hamilton, J. A., Methods for reducing seaplane take-off distances to standard conditions, *Aero. Res. Counc. Lond. curr. Pap.* 219, 14 pp. + 3 appendixes + 11 tables + 15 figs., 1956.

In this report are developed methods for the reduction of seaplane take-off distances to standard conditions of weight, wind, and ambient temperature. The expressions derived are applicable to the waterborne run and to the airborne run up to the 50-ft height point. The methods may be applied to take-off with simulated engine failure.

The theoretical results are in good agreement with measurements made on reciprocating-engined seaplanes of 9000-lb and 78,000-lb weight for winds up to 20 knots, weight changes of 20%, and a temperature range of 2 to 32C.

However, the general application of the corrections should be limited to temperature changes of less than 10C, weight changes

of less than 10%, and wind changes of less than 10 knots. These ranges should be adequate for the majority of flight trials conducted in one location. From author's summary

3331. Vannutelli, R., Paradoxical aspects of the helicopter (in Italian), *Aerotecnica* **36**, 1, 43–46, Feb. 1956.

To outsiders, and more particularly to those who are dealing with airplanes, the technique and the operation of the helicopter present aspects sometimes so unusual as to assume the character of a paradox.

Author quotes the most impressive of these paradoxes, classes them according to their causes, analyzes and discusses the causes themselves, singles out their corollaries, and derives some hints for a critical view of helicopter's present and future development. From author's summary

Aeroelasticity (Flutter, Divergence, etc.)

Book-3332. Bisplinghoff, R. L., Ashley, H., and Halfman, R. L., Aeroelasticity, Cambridge, Mass., Addison-Wesley Publishing Co. Inc., 1955, ix + 860 pp. $14.50.

Authors clearly state in the preface: "The objective of the authors in writing *Aeroelasticity* has been to provide both a text book for advanced engineering students and a reference book for practicing engineers." The book divides roughly into two halves; the first deals with the aerodynamic and structural tools and the second with applications of the tools to aeroelastic phenomena.

The first chapter is concerned with historical background of aeroelasticity and emphasizes its importance on modern design of airplanes.

Chapters 2, 3, and 4 deal with the deformation behavior of airplane structures under static and dynamic loads and exhibit systematically methods of analyzing the deformation, together with abundant illustrative examples.

Chapters 5, 6, and 7 are concerned with aerodynamic tools for aeroelasticians. They comprise steady and unsteady aerodynamics which are treated in the most comprehensive way.

Chapter 8 concerns static aeroelasticity; chap. 9 with flutter; and chap. 10 with dynamic response phenomena, together with abundant illustrative calculations.

Chapters 11 and 12 treat, respectively, the important subjects of aeroelastic model theory, and model design and construction; the final chapter is concerned with experimental techniques for aeroelastic phenomena.

Mathematical tools and extensive references are presented at the end of the book so as to help understanding and further studies of readers.

The book thus fulfills splendidly the objective of the authors. However, it would be more convenient for readers if numerical tables of the aerodynamic coefficients required for the illustrative calculations (at least) could be included in the appendix. Also, enriching the content with more experimental data seems desirable for showing the validity of the methods of analysis.

The book is an excellent elaboration and is strongly recommended as one of the most authoritative in the field of aeroelasticity. K. Washizu, Japan

3333. Orlik-Rückemann, K., and Olsson, C. O., A method for the determination of the damping-in-pitch of semispan models in high-speed wind tunnels, and some results for a triangular wing, *Flygtekn. Försöksanst. Medd.* 62, 26 pp. + 11 figs., Jan. 1956.

A technique is described for experimentally obtaining damping-in-pitch from the free oscillations of a wall-mounted half-model in a high-speed wind tunnel. The damping is read from a "dampometer" which basically uses the entire shape of the displacement-versus-time curve to give a reading of the damping instead of just the peaks. Thus relatively few oscillations are required to accurately define the damping. Experimental results are given for a sidewall-mounted triangular wing at Mach numbers from about 0.5 to 0.2. The supersonic results show substantially less damping than linear theory would indicate. The suggestion is offered that this may be due to the effect of the boundary layer on the trailing-edge shock wave, especially in the boundary layer on the wind-tunnel wall. L. H. Schindel, USA

3334. Eckhaus, W., Strip theory for oscillating swept wings in compressible subsonic flow, *Nat. LuchtLab. Amsterdam Rap.* F. 159, 14 pp. + 2 figs., Oct. 1955.

A general lifting surface of arbitrary shape is considered. Using linearized theory, the asymptotic expansion is derived for the downwash (valid for high aspect ratio and not too low frequency). The terms in this expansion depend only on the properties of the given chordwise section, and thus the present theory may be called a strip theory. For a wing swept through angle ϕ, the pressure is $\cos\phi$ times the sum of two-dimensional pressure and a small additional pressure given by an equation of the Possio type. The theory is shown to agree with results for incompressible flow when $M = 0$.

Possible methods are briefly considered for solving the approximate integral equation (1) by direct numerical solution and (2) by using the solution in terms of Mathieu functions given by Timman and van de Vooren [*Nat. LuchtLab. Amsterdam Rap.* no. F. 54, 1949] for a two-dimensional airfoil.

A. W. Babister, England

3335. Gaukroger, D. R., Wind-tunnel tests on the symmetric and antisymmetric flutter of swept-back wings, *Aero. Res. Counc. Lond. Rep. Mem.* 2911, 21 pp., 1955.

Wind-tunnel tests to determine the symmetric and antisymmetric flutter characteristics of a sweptback wing are described. The investigation covers the separate experimental treatment of the symmetric and antisymmetric body freedoms over a range of wing sweepback angles. Consideration is also given to the effect on critical flutter speed and frequency of variations in over-all center of gravity position, fuselage pitching moment of inertia, fuselage rolling moment of inertia, fuselage mass, and tailplane volume coefficient. The test results indicate that flutter speeds lower than the flutter speed of the wing with the root rigidly fixed may be obtained for a tailless aircraft with slight sweepback under unfavorable inertia conditions of the fuselage; for other sweepback and inertia conditions, the flutter speeds are likely to be equal to, or higher than, the fixed root speeds.

From author's summary

3336. Woodcock, D. L., Symmetric flutter characteristics of a hypothetical delta wing, *Aero. Res. Counc. Rep. Mem.* 2839, 23 pp., 1954.

This report considers the flutter characteristics of a hypothetical delta wing. It details the results of quaternary calculations showing the effect on the reduced critical speed of the shapes and relative natural frequencies of the first two normal modes of the aircraft. From these results the stiffnesses necessary to avoid flutter are deduced for two forms of wing structure. The aerodynamic forces have been obtained by using two-dimensional derivatives multiplied by the cosine of the quarter-chord sweepback in conjunction with strip theory applied to fore-and-aft strips. This procedure is of doubtful validity for the low-aspect-ratio wing considered. With this reservation, however, the results confirm the adequacy of the present Ministry of Supply wing-stiffness requirement. From author's summary

3337. **Leonard, R. W., and Hedgepeth, J. M., On panel flutter and divergence of infinitely long unstiffened and ring-stiffened thin-walled circular cylinders,** *NACA TN* 3638, 52 pp., Apr. 1956.

Paper presents very complete theoretical study of the stability of unstiffened and ring-stiffened infinite cylinders immersed in external and internal fluids flowing parallel to the cylinder axes at subsonic and supersonic Mach numbers. Most of the numerical work presented concerns the unstiffened empty case, but subsonic results are given for the stiffened shell. Conclusions are interesting, but reviewer hopes that parallel experimental studies will be undertaken and reported. W. S. Hemp, England

3338. **Milne, R. D., The unsteady aerodynamic forces on deforming, low aspect ratio wings and slender wing-body combinations oscillating harmonically in a compressible flow,** *Coll. Aero. Cranfield Rep.* 94, 42 pp. + 12 figs., July 1955.

A method for both subsonic and supersonic speeds, assuming slender-body theory, is used [cf. Merbt and Landahl AMR **6,** Rev. 3175]. The equivalent constant derivative for a deforming slender delta wing and the "rigid" force coefficients for pitching and plunging slender wing-body combinations are calculated after some simplifications. All results are subjected to the limitations given in cited paper by Merbt and Landahl.

H. G. Lew, USA

3339. **Rainey, A. G., Preliminary study of some factors which affect the stall-flutter characteristics of thin wings,** *NACA TN* 3622, 33 pp., Mar. 1956.

The results of an exploratory, analytical, and experimental study of some of the factors which might be of importance in the stall flutter of thin wings are presented. The factors considered were Mach number, Reynolds number, density, aspect ratio, sweepback, structural damping, location of torsion nodal line, and concentrated tip weights.

The importance of aerodynamic torsional damping in the stall flutter of thin wings has been demonstrated through comparison of regions of negative torsional damping and regions of flutter.

The results of a series of experiments on a thin wing tested at various lengths indicate that compressibility definitely alters the stall-flutter characteristics of wings of this type and that the compressibility effects appear to depend on the aspect ratio.

A brief study of the inertia effects of concentrated tip weights indicates that such effects can be important; however, the large number of parameters involved makes it difficult to generalize the results. An approximate analysis is presented for obtaining an estimate of the stall-flutter characteristics of particular wing-weight configurations.

Some of the other factors considered were found to be more or less significant; however, all the factors will require further study if their effects are to be more fully interpreted.

From author's summary

3340. **Tapscott, R. J., and Gessow, A., Charts for estimating rotor-blade flapping motion of high-performance helicopters,** *NACA TN* 3616, 19 pp., Mar. 1956.

Theoretically derived charts showing steady-state and first- and second-harmonic flapping coefficients are presented for helicopter rotors having hinged rectangular blades with a linear twist of 0°, −8°, and −16°. The charts, showing the rotor flapping coefficients for combinations of inflow ratio and blade pitch angle, are presented for tip-speed ratios ranging from 0.05 to 0.50.

The theory on which the charts are based does not contain any small-angle assumptions regarding blade-section inflow angles and velocities. These charts are therefore considered applicable, within the limits discussed, for flight conditions involving high inflow velocities and large regions of reversed velocity. Other than including an approximate allowance for stall in the reversed-velocity region, the charts do not include stall or compressibility effects. From authors' summary

3341. **Moore, F. K., Lift hysteresis at stall as an unsteady boundary-layer phenomenon,** *NACA TN* 3571, 32 pp., Nov. 1955.

With the problem of rotating compressor stall in mind, an unsteady boundary-layer calculation is made to find the unsteady increment of lift of a stalled elliptic airfoil in a flow of time-dependent incidence. The analysis indicates a counter clockwise hysteresis loop of the lift curve. At low reduced frequency, if the angle of attack undergoes harmonic oscillation, then the lift increment is also harmonic with a 90° phase shift, an elliptic hysteresis loop. If the angle of attack varies in a nonharmonic manner, then the lift does not have the same time dependence, and the idea of time lag is inappropriate.

The method of analysis follows that of Howarth. The airfoil is considered to be at maximum lift to simplify the analysis. For purpose of computing the amount of vorticity shed into the wake, the separation point is identified as the point of vanishing shear, just as in steady flow. Author points out that this assumption is questionable.

Reviewer believes that paper is a significant contribution to the literature. Further investigation along this line should be fruitful. Y. C. Fung, USA

3342. **Broadbent, E. G., Flutter problems of high-speed aircraft,** *Aero. Res. Counc. Lond. Rep. Mem.* 2828, 23 pp., 1955.

The flutter problems of high-speed aircraft are considered generally, and specific consideration is given to the new problems introduced by the use of new wing planforms. The theoretical and experimental results on the coupled ("classical") symmetrical flutter of swept (including "barbed" and cranked forms) and delta wings are reviewed and presented to show the effect and importance of the body freedoms of the aircraft on the critical flutter speed and frequency.

A criterion is proposed for deciding the "dangerous type" of fundamental normal mode to be considered in flutter calculations. The danger here is that the fundamental normal mode can combine with the body freedoms and give rise to a form of flutter which is independent of the wing torsional stiffness. It is suggested that the deciding feature is the shape of the nodal line in the fundamental mode. If it is such as to indicate rotation of the fore-and-aft wing sections near the tip, then the mode is considered to be dangerous. From author's summary

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 3167, 3245, 3273, 3324, 3341, 3381, 3382, 3403, 3418)

Book—3343. Pfleiderer, C., Centrifugal pumps for liquids and gases [Die Kreiselpumpen für Flüssigkeiten und Gase], Berlin/Göttingen/Heidelberg, Springer-Verlag, 1955, xi + 589 pp. DM 58.50.

Even the subtitle of this book, "waterpumps, ventilators, blowers and compressors," does not give a full explanation of its contents, as by "waterpumps" is meant centrifugal, mixed-flow and axial-flow pumps, if we follow the common usage of pumps as machines moving liquids. The book in this fourth edition is a better arranged and slightly changed version of the third (1949). Only pumps are treated in the second edition (1932), as in the first (1924), which was translated into French by Professor Bergeron. Superseding Neumann's "Centrifugal pumps" (Springer, 1906 and

1912), the early editions served as handbooks for pump designers at a time when centrifugals gradually displaced piston pumps in most fields. The further development, enhanced by the available high-speed drivers and better materials, is pictured in this last edition.

Due to lack of space, reviewer is constrained to describe the book by titles of its 15 chapters with some explanatory notes and make a few remarks at the end.

(A)–General behavior of the fluid in the pump.– Head, specific work and efficiency in hydro- and thermodynamic terms.

(B)–Principles of flow.– Bernoulli, impulse-momentum equations, circulation, potential flow of ideal fluids, flow with friction and changing density. Leakage through slots, disk-friction.

(C)–Flow-mechanism in impeller and work transfer from its vanes.– One-dimensional flow theory, Euler equation for infinite number of vanes, influence of finite number, friction, experimental coefficients, degree of reaction.

(D)–Impellers of different types and their properties.– Specific speed, number of vanes, efficiency, model laws.

(E)–Limitation by cavitation and sound velocity.– Highest suction lift, specific suction number for pumps and specific sonic number for blowers, optimization of entrance for both and exposition of their similarities and differences.

(F)–Centrifugal impeller with single curvature.– Calculation and design with numerical examples.

(G)–Mixed-flow impeller (double curvature), similarly to F.

(H)–Axial-flow impeller.– Blading with different degrees of reaction, blower design with elementary theory. Calculation with airfoil and cascades, also of diffusor.

(I)–Diffusors and volutes.– For single and multistage pumps.

(K)–Characteristic curves.– Calculation from theoretical, with friction and shock losses, change with types, affinity law.

(L)–Regulation.– Throttling, movable diffusor vanes.

(M)–Axial thrust and its balancing.

(N)–Examples of complete machines for gas and liquid.– Single and multistage, horizontal and vertical.

(O)– Multistage axial compressor.– Calculations with numerical example.

(P)– Strength calculations of the principal members.–Impeller-disk, critical speed of shaft.

Appendix. Self-priming pumps.– Watering and peripheral.

This lengthy enumeration falls short of giving the proper impression of the stimulating treatment of the various subjects. Still, American designers will notice some important shortcomings. In regard to pumps, their design is still an art, not a science, therefore refinements must manifest themselves in more definite design coefficients. The improvement from around 10% in efficiency to close to 90% or better for good types in the last 25 years and how they were brought about are not signified and even the examples are often of the second edition. One misses Thoma's complete characteristics for all possible operating conditions represented better by the Karman-Knapp circle diagram, which is getting more important for pump-turbines in power-storage schemes. In construction: American practice does not use diffusors for single-stage pumps, but volutes, which are designed for constant velocity disregarding friction and change of radius, with better results. Volutes are open, not narrowed to impeller width, permitting impeller cuts without impairing efficiency and change of case. Double volutes in place of diffusors are often used for multistage pumps.

Ball radio-thrust bearings take both radial and axial load, no need for two separate bearings as they are shown in horizontal and deepwell pump illustrations. Latter (taken from the second edition) was obsolete 25 years ago in American practice. Vertical pumps are standard for condensate pumps and used generally in the mixed-flow design for condenser circulating pumps, instead of horizontals with two double-suction impellers in parallel. Motor pumps with impeller on motor shaft extension and pump case on motor bracket up to 6–8 in. size, in general use here, are not mentioned, nor the gradual elimination of the packing box by the mechanical seal.

Regarding machines handling gas, Eck's "Ventilators" (1952), Kluge's "Centrifugal blowers and compressors" (1953), and Eckert's "Axial flow and centrifugal compressors" (1953), all in German, (Springer edition) treat the subject in greater detail. Notwithstanding reviewer's criticism, the book with its wealth of ideas belongs to the students', teachers', and designers' library.

A. Hollander, USA

3344. Acosta, A. J., and Bowerman, R. D., An experimental study of centrifugal pump impellers, *Calif. Inst. Technol., Hydrodyn. Lab.*, Pasadena, Calif., *Rep.* E–19.8, 27 pp. + 27 figs., Aug. 1955.

A series of very detailed experiments was conducted on four two-dimensional impellers (cascades with radial flow between plane annular shrouds) in which the inlet angle was the only variable. The experiments include head, torque, and efficiency measurement in addition to internal loss, velocity profiles, and pressure distribution. The results are compared with those of a well-designed commercial three-dimensional or Francis-type runner. The latter has better efficiency and flow rate than the two-dimensional ones.

A. Betz, Germany

3345. Costilow, E. L., and Huppert, M. C., Some effects of guide-vane turning and stators on the rotating stall characteristics of a high hub-tip ratio single-stage compressor, *NACA TN* 3711, 52 pp., Apr. 1956.

Rotating stall characteristics of several guide-vane–rotor and guide-vane–rotor–stator configurations were investigated. Guide vane turning angles used were -22.5°, 0°, 22.5°, and 40°. The stage hub-tip ratio was 0.9.

Results indicate that the initial rotating stall point, number of stall zones formed, and stall propagation rate of a configuration depend not only upon blade-row inlet angle and pressure-rise characteristic, but also upon the over-all characteristics of the multiblade row unit as well. The addition of stators to a particular guide-vane–rotor configuration generally increased the flow coefficient where rotating stall was initially encountered, and lowered the stall propagation rate. The number of stall zones formed in the annulus did not appear to depend upon guide-vane turning or the presence of stators.

From authors' summary by A. S. Andes, USA

3346. Peschka, W., Axial compressors as sound sources (in German), *Ing.-Arch.* **10**, 1, 80–95, 1956.

3347. Etinberg, I. E., Application of Lesokhin's method for designing of Kaplan turbine vanes and computation of the cavitation parameter σ (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **21**, 163–179, 1955.

The basis of the method is the assumption that (1) the flow in the runner of a Kaplan turbine does not show any radial component of speed, and (2) that the flow around the vanes in each cylindrical section of the runner is equal to the flow around the vanes of a straight infinite cascade of airfoils, resulting when the cylindrical section of the runner in question is projected into a plane. Author attempts to refer the calculation of runner vanes and their three-dimensional flow to the calculation of a straight, plane and infinite cascade of airfoils. To this latter calculation method, the well-known singularity method is applied, in which the airfoils are replaced by a continuous distribution of vortex and source sinks. Furthermore, a source is arranged at each inlet edge of blade, thereby attaining a round shape of the inlet edge. At first the

mean line of the airfoil in cascade is calculated. The second step investigates the profile form.

For the calculation the following will be assumed as existing: Distance of the airfoils t, vane length l, maximum thickness δ rounding-off radius at the inlet edge ρ, angle at the trailing edge θ, and the mean flow without cascade of airfoils w_∞. The calculation is conducted according to the method of successive approximations, whereby the speeds produced by the airfoils in cascade were taken from design charts. In calculating the induced speeds of the isolated airfoil, the local curvature of the mean line is to be considered closely.

Reviewer comments that the process is an approximate, however sufficiently exact, calculation method of the plane, straight, and infinite cascade of airfoils. The application of the method in calculating the form of the vanes of Kaplan runners is entirely groundless and hardly permissible for the following reasons: (1) In the runner of the Kaplan turbine, radial speeds cannot be avoided [Strscheletzky, "Significance of the radial speed component in the runner of Kaplan turbines," *Voith-Konstruktion und Forschung* no. 1, 1955]. (2) The flow around the vanes of an axial flow runner is not equivalent to a two-dimensional flow through a straight, plane, and infinite cascade of airfoils [AMR **5**, Rev. 3205].

The application of this method for calculating Kaplan runners, having usually a few vanes and rather small hub ratios may lead under some circumstances to considerable errors. The designer who intends to calculate Kaplan turbine runners on the basis of this method must rely fully on expensive tests.

M. Strscheletzky, Germany

3348. **Dittrich, R. T., and Graves, C. C., Discharge coefficients for combustor-liner air-entry holes, I. Circular holes with parallel flow,** *NACA TN* 3663, 39 pp., Apr. 1956.

Practical, empirical information is given and method of application to combustor-liner design is demonstrated. Discharge coefficients, corrected for pressure-ratio effects, were correlated with a flow parameter which represents approximately the square of the ratio of the jet velocity to the parallel flow velocity. Studies were limited to parallel flows on the outside, or high-pressure side, of the liner only. Ranges of variables covered were: hole diameter 0.125 to 1.50 in., external-flow passage height 0.74 to 2.23 in., wall thickness at hole 0.040 to 0.500 in., external parallel flow velocity 0 to 500 fps, static pressure drop across hole 0.007 to 3.20 psi, boundary-layer thickness of external parallel stream 0.04 to 0.10 in., static pressure of external stream 7.35 to 25 psia. Internal parallel flow was zero, but according to authors' results should be applicable whenever the jet velocity through the hole exceeds the internal parallel flow velocity. Of the parameters investigated, the external parallel flow velocity and static pressure ratio were the most significant.

Reviewer believes that demonstrated importance of external flow velocity indicates a need to extend studies to include nonzero internal velocities.

C. L. Coldren, USA

3349. **Cheers, F., Development of an air injector,** *Nat. Res. Counc. Canad. mech. Engng. Rep.* MT-31, 11 pp. + 11 figs., Mar. 1956.

To obtain high flow rates at low pressure from an existing low-flow-rate high-pressure compressor, author designs simple air injector. One-dimensional compressible flow relations are taken from Laidlaw [AMR, **4**, Rev. 3673]. Agreement of finished injector performance with theoretical is fair at low primary jet pressures but becomes worse at higher pressures. Jet noise can be decreased by use of a convergent-divergent primary nozzle. In open-ended secondary nozzle, flow is unsteady and velocity distribution uneven. However, when a high drag test rig was attached to the injector, flow and velocity profile evened out.

E. G. Chilton, USA

Flow and Flight Test Techniques

(See also Revs. 3267, 3272, 3298, 3316, 3317, 3325, 3335, 3349)

3350. **Hopkins, E. J., and Sorensen, N. E., A device for vortex-core measurements,** *J. aero. Sci.* **23**, 4, 396–398 (Readers' Forum), Apr. 1956.

Device is small circular-cylinder windmill: rotational speed is maximum when instrument is at center of vortex. Preliminary investigation up to 200 fps showed device locates vortex cores accurately. Design would need modification for high-speed use.

R. C. Pankhurst, England

3351. **Leist, K., Experimental determination of the distributions of pressure, temperature, and stress in fast-running turbine rotors** (in German), *Z. Fluguiss,* **4**, 3/4, 128–140, Mar./Apr. 1956.

Paper describes experimental techniques in detail and gives results of preliminary measurements.

Pressure distributions were measured at 140 stations on one of the blades on a single rotor driven by cold air at speeds up to 12,000 rpm (chord Reynolds number 2×10^6, Mach number 0.5) and for different blade spacings. The temperatures were measured by thermocouples placed at four points in a blade and at several points in the disk of a rotor driven by hot air. The stress distributions were measured in flat disks with eccentric holes by means of stroboscopic-photoelastic observations.

N. H. Johannesen, England

3352. **Herning, F., Investigation of pressure distribution near measurement throats in a 1000-mm pipe** (in German), *Brennstoff-Wärme-Kraft* **8**, 3, 118–125, Mar. 1956.

Although direct flow calibration was not possible, valuable information is presented on wall pressures near standard nozzles and standard and segmental orifices. Aperture ratios m of 0.1 to 0.55 were studied for gas flows in the Reynolds number range 2 to 6×10^5. In this large pipe the minimum pressure for standard orifices was found 0.1 to 0.15 D closer to the plate than the standard average value. The minimum for nozzles was further downstream and that for segmental orifices further yet, but both are closer to the plate than previously reported for smaller pipe. Author thus infers a downstream shifting of vena contracta with increase in relative roughness.

Measurements are also interpreted in terms of the pressure rise before and fall after the various devices, the pressure loss, and the correction to the discharge coefficient α for nonstandard locations of the pressure piezometers. This latter is shown to diverge significantly from standard results. The loss in percentage of working pressure is a unique function of $m \cdot \alpha$. Study of the effect of different-sized piezometers is inconclusive due to pressure fluctuations giving uncertain, and even false, values. Suggestions are made for keeping piezometers out of zone of fluctuations.

Reviewer believes paper will prove most valuable to those interested in standardization of throat-type flow meters.

J. M. Robertson, USA

3353. **Thibessard, G., Discharge experiments with orifices on the end of a pipe** (in German), *Brennstoff-Wärme-Kraft* **8**, 3, 116–117, Mar. 1956.

Careful tests in the Reynolds number range 10^4 to 10^5 indicate that the discharge coefficients of pipe orifices (with free discharge from smooth pipe) for area ratios m of 0.1 to 0.65 are 0.5 to 1.0% higher than the VDI standards for such orifices in a continuous pipe line. The same orifices tested with a following length of pipe indicated coefficients 0.1 to 0.4% high. Thus author recommends that coefficients for pipe orifices be taken somewhat higher than for the same orifice plate in a pipe line.

Similar tests for orifices at the end of a rough pipe indicated a linear increase with m of the discharge coefficient over that for smooth pipes. J. M. Robertson, USA

3354. Wuest, W., Theory of Bourdon tubes (in German), *Ing.-Arch.* **24**, 2, 92–110, 1956.

Under well-defined assumptions, stresses and displacements of Bourdon tubes (meant for internal pressures between 100 and 10,000 kg/cm^2) with special cross section are calculated and compared with experimental data. C. B. Biezeno, Holland

3355. Johnson, R. C., Averaging of periodic pressure pulsations by a total-pressure probe, *NACA TN* 3568, 30 pp., Oct. 1955.

Theory and experiment are compared for total-pressure probe periodically passed across edge of a 0.75-in. high-velocity air jet. Probes range from 0.012 to 0.047-in. diam and from 0.01 to 15 in. long. Frequency ranges from 3 to 50 cps. Probe velocity is always small compared with air velocity. Stagnation pressure ratio ranged from 0.15 to 1.8. Optimum probes should be of small diameter and long, consistent with speed of response requirements. Good agreement with theory was obtained when maximum Reynolds number in probe was less than 8000. Derivation of equations, sample calculations, tabular data, graphs, and illustrations are included. G. R. Carlson, USA

3356. Khavkin, L. P., On measurements of low pressures in different gases with a thermocouple gage (in Russian), *Zh. tekh. Fiz.* **25**, 4, 726–732, Apr. 1955.

Calibration of the vacuum thermocouple gage of Soviet manufacture, designated LT-2, for different gases in the range of pressures from 0.001 to 1 mm Hg is discussed. Simplified theory indicates that the sensitivity coefficient $\partial p/\partial E$, E being thermocouple voltage, is inversely proportional to the product of the heat conductivity Λ of the gas and the accommodation coefficient a of the gas relative to the material of the heated wire. From accepted values of a relative to platinum and Λ for H_2, Kr, He, Ne, CO, Ar, and CO_2, the ratios q of the sensitivities in these gases to that in air were predicted and well verified by experiments.

Simplified arguments for a to take the form $1-\exp\{-\beta(M^{1/2})\}$, where M is the molecular weight of the gas and the constant β absorbs the inverse square root of a mean characteristic temperature T of the gas cloud, are given. From 900 measurements of q, the value of β of 0.244 was inferred. The formula then predicts well the classical experimental accommodation coefficients for platinum and provides a simple means for measuring those for other gases, as was done for CH_4, C_2H_2, C_2H_4, C_2H_6, H_2S, and SC_2. Discrepancy of formulas for a and q and experiments of some 30% were noted for C_2H_4 and C_2H_6. These could be due to uncertainty in the ratio of specific heats ∂ for these gases, a value present in the formula for q. M. V. Morkovin, USA

3357. Poggi, L., A new kind of differential micromanometer (in Italian), *Pubbl. Fac. Ing. Univ. Pisa* (16), no. 752, 3 pp., 1955.

A body of revolution floating in a fluid and suspended on two parallel filaments turns under the effect of a small torsional moment about its vertical axis by an angle that is a function of the change of the fluid level. Small changes in fluid level are translated into large angular movements which can be read conveniently by means of a mirror system or a mechanical pointer. This principle is applied to the design of a micromanometer. Main advantages over conventional vertical or oblique tube manometers are elimination of adverse effects of meniscus shape, adhesion forces, and viscosity of the fluid on manometer readings. Several design aspects, means of calibration, and feasibility of a null method (by adding or draining known amounts of fluid compensating for change of fluid level due to change of pressure differential) are discussed. Method looks very promising for small pressure differentials down to fractions of millimeters of water. Unfortunately, no figures are given of accuracies actually obtained with author's prototype. H. J. Ramm, USA

3358. Kozlov, B. K., Flow pattern of gas and fluid mixtures and their steadiness threshold in vertical tubes (in Russian), *Zh. tekh. Fiz.* **24**, 12, 2285–2288, Dec. 1954.

Study was carried out by cinematography of air-water mixtures in transparent 25-mm diam pipe, varying the proportions of air/water from 0 to 1.0, and the velocity of the mixture from 0.1 to 20 m/sec under a mean pressure of 1.5 atmos. Author finds six forms of motion of mixture, from small bubbles of air in water through complete emulsion to droplets of water in air, and establishes graph limiting these forms in function of the various parameters of flow. A. G. Foster, England

3359. Zorn, H. C., Measuring flow velocities and determining lines of main current in water-beddings by means of photogrammetry (in Dutch), *Ingenieur* **68**, 6, B.23–B.27, Feb. 1956.

The method allows more than one target to be used at a time. The photographic background is explained; the photogrammetric details can be found in the several handbooks on photogrammetry. From author's summary

3360. Geller, E. W., An electrochemical method of visualizing the boundary layer, *J. aero. Sci.* **22**, 12, 869–870 (Readers' Forum), Dec. 1955.

3361. Frederick, C. L., and associates, Automatic pressure measuring systems used with high-speed wind tunnels, AGARDograph 10, 51 pp., June 1955.

A survey of the principal devices and typical systems developed for automatic pressure measurement in high-speed wind tunnels in the United States. From author's summary

3362. Johnson, J. B., Convection type manometer, *Rev. sci. Instrum.* **27**, 5, 303–305, May 1956.

A manometer is described which depends on heat convection rather than on molecular heat conduction. Its range may be from a few mm of Hg to atmospheric pressure or more. Its performance for various conditions is explored, including its possible use as an inclinometer. From author's summary

3363. Cooke, J. R., The use of quartz in the manufacture of small diameter pitot tubes, *Aero. Res. Counc. Lond. curr. Pap.* 193, 7 pp. + 6 figs., 1955.

This note describes the method of manufacture of small quartz-tipped pitot tubes(down to 0.005 in. outside tip diam) which have been used successfully for boundary-layer measurements on small models in a supersonic wind tunnel.

Tests have been made (a) of the effects of taper and end finish on the accuracy of measurement and (b) of the effect of the inside diameter of the tip (for a standard taper) on response rate. For a given inside tip diameter the tapered quartz tubes gave a faster response rate than the stainless-steel hypodermic tubes previously used. From author's summary

3364. Nethaway, J. E., Low speed wind tunnel calibration of a Mk. 9a pitot-static head, *Aero. Res. Counc. Lond. curr. Pap.* 244, 3 pp. + 1 table + 3 figs., 1956.

Note describes the calibration of a Mark 9A pitot-static head in the No. 2 11½-ft wind tunnel. The results show the variation of pitot and static pressure error coefficients with incidence, at constant tunnel speed. From author's summary

3365. Tietjens, O., The wind tunnel at the Indian Institute of Science, Bangalore, South India (in German), *Z. Fluguiss.* **4**, 1/2, 1–9, Jan./Feb. 1956.

As a part of a larger expansion program of the Department of Aeronautical Engineering in India a description of a new wind tunnel is given. Starting with the desirable qualities of a wind tunnel it is explained that the power required for an open-circuit wind tunnel is smaller than for the closed-circuit type. It is shown that any disturbances like winds or gusts at the entrance or at the exit of an open-circuit wind tunnel can be eliminated by means of suitable screens. If these screens are placed where the velocity of the air sucked in by the propeller is still very small, little power is required to overcome frictional losses due to the screens. With comparatively small cost, a wind tunnel has been built that has (1) a very uniform velocity distribution, (2) a very low turbulence level, and (3) the possibility of placing engines and gas turbines in the wind tunnel for testing purposes.

From author's summary

3366. Vandrey, F., and Wieghardt, K., Experiments on a slotted-wall working section in a wind tunnel, *Aero. Res. Counc. Lond. curr. Pap.* 206, 10 pp. + 8 figs., 1955.

The present investigation was undertaken in order to develop a test section for a planned water tunnel with the correction properties of a free jet, but with a considerably greater length than a conventional open working section.

The experiments were carried out in air ($V = 96$ fps) with a jet of 5-in. diam and 30-in. length, enclosed in a cage of 16 longitudinal rods with an opening ratio of 18% of the total boundary. The cage was surrounded by a rigid cylinder of 12½-in. diam representing the outer boundary of the water tunnel.

The main results were: The velocity distributions of the jet in the cage are about the same as in a free jet at half the distance from the nozzle. The static pressure in the cage is constant. Pressure distributions of models in the cage are the same as in a free jet. Even considerable alterations of the design and deformations of the cage have practically no influence on the results.

From authors' summary

3367. Vandrey, F., Further experiments with a slotted-wall test section, *Aero. Res. Counc. Lond. curr. Pap.* 207, 7 pp. + 9 figs., 1955.

As shown by previous experiments, a slotted-wall test section is especially suitable for a water tunnel intended for the testing of long models. The present report deals with the transition from this type of test section to the diffuser.

The main results are: The optimum diameter of the diffuser entry is about 10% greater than the diameter of the nozzle (for 30% losses in the test section, less for smaller losses). A gap should be left between the end of the slotted-wall and the diffuser entry. A model in the test section has very little influence on the pressure in the diffuser entry.

Experiments both in air and water are in good agreement.

From author's summary

3368. Thomson, T. A., Temperature control of blow-down supersonic tunnels, *J. roy. aero. Soc.* **60**, 541, 67–70 (Technical Notes), Jan. 1956.

3369. Spence, A., Leathers, J. W., and Kirby, D. A., Low-speed tunnel model tests on tailplane rolling moments in sideslip, *Aero. Res. Counc. Lond. Rep. Mem.* 2941, 20 pp., 1955.

To provide data for stressing purposes, measurements have been made of the effect of sideslip on the rolling moment on a 41.5° sweptback tailplane mounted at three heights on the fin of a 1/5th scale model of a single jet aircraft with a 40° sweptback wing. Incidence and tailplane setting were varied, and the effects of rudder deflection were obtained with the tailplane at the top of the fin. Brief results on a delta aircraft model with a delta tailplane at the top of the fin are also included.

(*a*) At zero tailplane lift, for tail heights 0.31, 0.62, and 0.99 times the fin height external to the body, the values of $(-l_{v\,tail})$ are 0.111, 0.172, and 0.199, respectively. These values are increased slightly by increase of incidence.

(*b*) The variation with tailplane lift is as estimated for the tailplane alone.

(*c*) Deflecting the rudder changes the rolling moment on the high tailplane in proportion to the change of side force on the fin and rudder. A smaller effect would be expected on lower tailplanes where the flow round the body contributes more to the rolling moment.

From authors' summary

3370. Thomson, T. A., Experiments on a temperature recovery system for a blow-down supersonic wind-tunnel, *Aero. Res. Labs., Melbourne, Austral. Rep.* A.91, 39 pp. + 13 figs., Feb. 1955.

Tests were made on a packed glass-wool heat regenerator in the settling chamber of a small supersonic wind tunnel. It was found that the temperature uniformly dropped about 0.7% of its initial value during the time interval where theory indicated uniform outflow temperature. This rate of decrease continued in subsequent time intervals where a more rapid decrease was expected. Feasible processes which might explain these phenomena were exhaustively investigated without entirely conclusive results. Reviewer suggests that release of heat stored in components other than the glass-wool might have been one of the contributing factors.

J. S. Holdhusen, USA

3371. Johnson, F. V., Dynamics of instrument bearing torque testing, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-178, 6 pp. + 4 figs.

Establishing standards for measuring and specifying instrument ball-bearing torques is known to require devices of mechanical precision. It is less generally recognized that it also requires the precise concepts and language of dynamic control and measurement. While there are many types of torque-testing devices available, most are designed and used on a purely empirical basis, having outputs more or less related to bearing torque. As a basis of establishing standards of bearing excellence, such instruments should provide a true torque measurement as a function completely correlated with the performance of the instrument.

From author's summary

Thermodynamics

(See also Revs. 3193, 3281, 3348, 3352, 3353, 3354, 3357, 3362, 3393, 3413, 3423, 3435, 3439)

Book—3372. Einstein, A., Investigations on the theory of the Brownian movement, New York, Dover Publications, Inc., 1956, 119 pp. $1.25 (paperbound).

3373. Ramsey, N. F., Thermodynamics and statistical mechanics at negative absolute temperatures, *Phys. Rev.* (2), **103**, 1, 20-28, July 1956.

Systems with an upper bound for the energy can possess a negative temperature. The transition from positive T^{-1} to negative T^{-1} is continuous, negative temperatures being "hotter" than positive ones. Author discusses changes in formulation of thermodynamic and statistical theorems to be made in order that these are valid for both positive and negative temperatures. Author discusses

spin systems at negative temperatures and mentions some possible applications of systems at negative temperatures.

D. ter Haar, England

3374. Saxena, S. C., On the two schemes of approximating the transport coefficients (Chapman-Cowling and Kihara), *J. phys. Soc. Japan* **11,** 4, 367–368, Apr. 1956.

The three elementary transport coefficients and the isotopic thermal separation ratio have been evaluated over an extensive range of temperatures by utilizing the expressions derived on the approximation procedure due to Kihara, for the Lennard-Jones 12:6 model. These values have been compared with the corresponding, and a still higher-order approximation, values calculated on an alternative approximation scheme of Chapman and Cowling. The comparison of the results obtained on the two schemes of approximation indicates that the simple expressions of Kihara are more accurate and preferable even to the corresponding higher approximation expressions of Chapman and Cowling.

From author's summary

3375. Srivastava, B. N., and Saxena, S. C., Generalised relations for the thermal diffusion factor of inert gas mixtures with one invariable constituent, *Physica* **22,** 4, 253–262, Apr. 1956.

The variation of the thermal diffusion factor α for binary mixtures of inert gases, when one constituent is kept fixed and the other varied, has been investigated and semi-empirical formulas have been derived for the variation of α with the proportionate mass difference of the molecules. These results have been explained in terms of the Chapman-Enskog formula for the case of Lennard-Jones 12:6 model by utilizing the experimentally obtained unique dependence of the force constants ϵ_{ij} and ν_{ij} on the molecular mass of the variable constituent for a given series of mixtures. The same considerations have been applied to isotopes of monatomic molecules and suitable formulas have been deduced for α, ϵ_{11} and ν_{11}. The formulas have been tested by calculating the force constants of radon. From authors' summary

3376. Hill, N. E., Mutual viscosity and diffusion in liquid mixtures, *Proc. phys. Soc. Lond. (B)* **68,** 424, 209–212, Apr. 1955.

A theory of diffusion in liquid mixtures is proposed which shows that the intrinsic diffusion coefficient $\mathbb{D}_A$ of the substance A in a mixture of A and B in which the mole fractions are respectively f_A and f_B is

$$\mathbb{D}_A = kT/6(f_A\eta_A\sigma_A + f_B\eta_{AB}\sigma_{AB})$$

where η_A is the viscosity of the pure liquid A, η_{AB} is the mutual viscosity of the mixture, and σ_A and σ_{AB} are intermolecular distances.

This leads to values of D, the measured diffusion coefficient, which are in good agreement with the experimental values, both in the limiting case when the concentration of one component is very low, and for 50% mixtures. From author's summary

3377. Biot, M. A., Thermoelasticity and irreversible thermodynamics, *J. appl. Phys.* **27,** 3, 240–253, Mar. 1956.

A unified treatment is presented of thermoelasticity by application and further developments of the methods of irreversible thermodynamics. The concept of generalized free energy introduced in a previous publication plays the role of a "thermoelastic potential" and is used along with a new definition of the dissipation function in terms of the time derivative of an entropy displacement. The general laws of thermoelasticity are formulated in a variational form along with a minimum entropy production principle. This leads to equations of the Lagrangian type, and the concept of thermal force is introduced by means of a virtual work definition. Heat conduction problems can then be formulated by the methods of matrix algebra and mechanics. This also leads to the very general property that the entropy density obeys a diffusion-type law. General solutions of the equations of thermoelasticity are also given using the Papkovitch-Boussinesq potentials. Examples are presented and it is shown how the generalized coordinate method may be used to calculate the thermoelastic internal damping of elastic bodies. From author's summary

3378. Vlieger, J., and De Groot, S. R., On the theory of reciprocal relations between irreversible processes. Statistical foundations of thermodynamical fluctuation theory in moving media, *Physica* **20,** 7, 372–382, July 1954.

Recently S. R. de Groot and P. Mazur have extended Onsager's proof of reciprocal relations between irreversible processes to the case of vectorial and tensorial phenomena. In the derivation, expressions are used for certain averages of fluctuations of the variables α_i^μ and β_k^μ, which describe the state of a great number of cells μ, into which the system is divided. These averages are calculated with the help of the probability distribution

$$P \sim \exp\{\Delta S(\alpha_i^\mu, \beta_k^\mu)/k\} \qquad [1]$$

where ΔS is the deviation of the entropy from its equilibrium value.

The use of formula [1] in the case where the state variables include barycentric velocities of the material elements should be justified. This is possible, but in the present paper a slightly simpler method is preferred to find the averages of the fluctuations, necessary for the proof of reciprocal relations. It turns out that, for their derivation, distribution functions for the state variables of one or two cells suffice. From statistical calculations these are found to be

$$P_1 \sim \exp(\Delta S_1^0/k) \qquad [2]$$

$$P_{12} \sim \exp\{(\Delta S_1^0 + \Delta S_2^0)/k\} \qquad [3]$$

where ΔS_i^0 is a quadratic form in the state variables of the cell i (= 1, 2), including barycentric velocities.

In the theory, independent state variables are used in a natural way, in contrast with De Groot and Mazur's (and Casimir's) treatment, where dependencies exist among the state variables as a consequence of the conservation of mass and energy. One could, of course, eliminate a number of variables, so as to obtain a set of independent state variables, but this complication can be avoided by using the distribution functions [1] and [2] instead of [3], as is done in this paper. From authors' summary

3379. Owe Berg, T. G., On the thermodynamics of mixtures, *Appl. sci. Res.* (A) **4,** 5/6, 393–404, 1954.

The difference between two equilibrium states is composed of configurational and thermal change. The thermal change is composed of a reversible part $\Delta E^r_{th.}$, $\Delta S^r_{th.}$ and an irreversible part $\Delta E^i_{th.}$, $\Delta S^i_{th.}$. The second law of thermodynamics, $\Delta E = T\,\Delta S$, is applicable to the total change if $\Delta E_{conf.} - T_0\Delta S_{conf.} = -(\Delta E^i_{th.} - T_0\Delta S^i_{th.}) = A$ or if $\Delta E^i_{th.} = T_0\Delta S_{conf.}$, $\Delta S^i_{th.} = \Delta E_{conf.}/T_0$, T_0 being the temperature at which the change occurs. At the particular temperature $T_0 = T_b$ we have $\Delta E_{conf.} = T_b\Delta S_{conf.}$. Hence, the process is reversible at this particular temperature. The heat of mixing (reaction, neutralization, etc.) at the temperature T_0 is $T_0\Delta S_{conf.} + \int_0^{T_0} \Delta C_p dT$, where ΔC_p is the change in specific heat. The entropy of mixing at the temperature $T_0 \neq T_b$ is $\Delta S_{conf.} + \Delta S^i_{th.}$. These formulas are applied to mixtures and illustrated by the derivation of vapor pressure formulas and by the calculation of the heat of neutralization of HCl with NaOH.

From author's summary

3380. Leidenfrost, W., Measurement of true specific heat of solid bodies (in German), *ATM* no. 243, 93–94, Apr. 1956.

Book—3381. **Schimanek, E., Energy conversion in heat engines [Energiaátalakulás Höerögépekben]**, Budapest, Akadémiai Kiado, 1954, 208 pp.

In the introduction, the basic dynamic and thermodynamic principles are given. The next two chapters are devoted to the basic principles of reciprocating steam and gas engines, including gasoline and diesel motors. The turbine (steam and gas) are treated next. Improvements of the ideal cycle and the irreversible processes are the subject of the following two chapters. The last chapter deals with design considerations of heat engines—reciprocating engines as well as turbines. Finally, a few words are included about possible future developments.

Author points out that the book is aimed toward use in theoretical as well as design work. Actually, it falls short in both respects. It is, at best, a first introduction to the field. This book shows again that the large field cannot be covered in 208 pages.

T. P. Torda, USA

3382. **Ljunggren, K., Applications of radioisotopes in steam power plants** (in Swedish), *Tekn. Tidskr.* **86**, 20, 467–470, May 1956.

Heat and Mass Transfer

(See also Revs. 3192, 3193, 3238, 3260, 3282, 3351, 3356, 3362, 3368, 3370, 3372, 3375, 3381, 3382, 3425)

Book—3383. **Fourier, J., The analytical theory of heat** (translated by A. Freeman), New York, Dover Publications, Inc., 1955, xxiii +466 pp. $1.95 (paperbound).

The most striking thing about the exposition of Fourier is the completeness of his presentation. He parlays the phenomenological equations of Biot, Newton, and others into the traditional differential equations in the simple coordinate systems. He was aware of the basic modes of heat transfer and recognized heat storage, heat conduction, heat convection, and heat radiation. The parameters of the various modes seem to be understood. Having established the differential equations and expounded the fundamental notions, he proceeds to develop solutions to the equations for various boundary conditions. As a means to this end he uses trigonometric series and integrals. He shows that a function may be expanded as an infinite trigonometric series and determines the expression for the general coefficient. He recognizes that discontinuous functions are expandable by his method and is perhaps a little over optimistic when he says that "any function whatsoever" is so expandable. The infinite trigonometric integral is developed. He concludes his work with a review of the basic notions of heat transport.

The style of writing is more like an essay than a technical exposition, and at times he takes much space to say little. However, when viewed with respect to the time of this work, and the great step forward it represents, this criticism becomes invalid. Students of heat transfer will find this work has many absorbing facets, and that many rewarding hours of constructive leisure are in store for those who wish to follow the author's development of a new part of physical science. The library of no person who is serious about heat transfer should be without this volume. It is an initial contribution to the field, and reviewer is unaware of another of similar stature.

The translation of this "old classic" is fluid and very readable. The translator's footnotes are ample and valuable.

C. R. Mischke, USA

3384. **Datsev, A. B., A thermal conductivity problem in two-dimensional multilayered solids** (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **101**, 5, 813–816, 1955.

The fundamental significance of the theory of potential for the Laplace equation is well known. Starting, in the mathematical theory of heat conduction, with the singular solutions corresponding to instantaneous point sources of heat, an analogous theory may be developed also for the differential equation of conduction of heat. The resulting thermal potentials enable us to reduce boundary-value problems of this latter equation to integral equations. This efficient way of treating a number of important questions was extensively used by many earlier authors [see, e.g., Levi, *Annali di Matematica* 1908; Gevrey, *J. Math. pures appl.* 1913].

The greatest value of the paper under consideration is that it shows how the above method must be modified in the case of multilayer cylindrical bodies and for two-dimensional problems in multiconnected domains. The procedure is explained in detail on the advanced case of heat conduction in the composite region consisting of an infinite homogeneous cylindrical core of arbitrary cross section, surrounded by another homogeneous medium extending in all directions to infinity. The solution is given under quite general initial conditions and for continuous variation both of the temperature and of the flux at the surface of separation of the two media. The method can be applied also for other types of the space conditions.

Paper is a substantial contribution to theoretical treatment of advanced problems of heat conduction. Of course, practical calculations may be very complicated.

V. Vodička, Czechoslovokia

3385. **Datsev, A. B., A thermal conductivity problem in three-dimensional multilayered solids** (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **101**, 6, 1019–1021, 1955.

This paper extends the method of solving advanced boundary-value problems on heat conduction by means of thermal potentials [see preceding review] to three-dimensional cases. Detailed attention is paid to the composite body consisting of two homogeneous isotropic media: the inner part is bounded by a closed surface S, the external part is made from another material and extends in all dimensions to infinity. Assumed are general initial conditions and continuous variation both of the temperature and of the flux at the surface separating the two media.

Author also indicates the possibility of applying the method to problems of heat conduction in multilayered and multiconnected three-dimensional solids. The considerations are analogous to those used in a previous article about two-dimensional cases [see preceding review].

V. Vodička, Czechoslovokia

3386. **Liebmann, G., The solution of transient heat flow and heat transfer problems by relaxation,** *Brit. J. appl. Phys.* **6**, 4, 129–135, Apr. 1955.

A new finite-difference approximation is presented for the solution of the parabolic partial-differential equation of transient heat conduction. By choosing two coordinates as space and time variables, the difference equation can be put into a form analogous to the approximation for steady two-dimensional temperature fields. With this finite-difference scheme the usual relaxation technique can be applied directly.

The relaxation solutions are found to be unusually stable even for relatively large time intervals. It is also shown that Richardson's extrapolation can be applied to improve convergence by reducing the truncation error to $0(\delta t)^2$. The method is generalized in two space coordinates, and several examples are given along with a discussion of the method for heat exchange at exposed surfaces.

The reported advantage of the new over the old method is that the inherent stability of the relaxation solutions allows the choice of larger time intervals. Unfortunately, the technique of relaxation itself usually involves somewhat more labor than the old method of forward iteration.

P. J. Schneider, USA

3387. Sarjant, R. J., and Slack, M. R., Internal temperature distribution in the cooling and reheating of steel ingots, *J. Iron Steel Inst. Lond.* **177**, part 4, 428–444, Aug. 1954.

The thermal history of steel ingots from casting to rolling has been investigated by combining a technique developed for the numerical integration of the heat-flow equation in two dimensions with experimental work on various casting and reheating practices. Track time and reheating practice are related to the thermal efficiency and the temperature saturation necessary for good rolling. An expression is derived for the optimum track time which results in the most rapid equalization of surface and center temperature, although the limiting factor in the reheating for rolling may be the attainment of uniformity of surface temperature.

From authors' summary

3388. Muncey, R. W., Calculation of temperature rise with intermittent heating, *Austral. J. appl. Sci.* **7**, 1, 29–37, Mar. 1956.

Calculations of the response of a building to the input of heat have heretofore been based on assumptions which are generally invalid. This paper describes the development of a calculation technique wherein a comparison thermal network is found of such a type that its response can be calculated directly. The technique is illustrated with examples and its extension to electrical analogies discussed. From author's summary by J. Persh, USA

3389. Rannie, W. D., Heat transfer in turbulent shear flow, *J. aero. Sci.* **23**, 5, 485–489, May 1956.

Paper discusses heat transfer in turbulent shear flow along a smooth wall from the point of view of von Karman's paper on the analogy between fluid friction and heat transfer. Methods of extending analysis to higher Prandtl numbers by using a suitable velocity profile for region close to the wall are suggested. Resulting analysis gives results in reasonable agreement with data for Prandtl numbers up to about 50. Reviewer found paper clearly written.

Author states that velocity profile proposed by reviewer is not consistent with heat-transfer measurements at higher Prandtl numbers. That is true of work given in an early paper, but in later work [*NACA TR* 1210] the eddy diffusivity close to the wall is modified to account for effect of kinematic viscosity. Results are in agreement with available heat- and mass-transfer measurements at Prandtl and Schmidt numbers up to 3000.

R. G. Deissler, USA

3390. Lees, L., Laminar heat transfer over blunt-nosed bodies at hypersonic flight speeds, *Jet Propulsion* **26**, 4, 259–269, 274, Apr. 1956.

Paper treats two limiting cases of laminar heat transfer over blunt-nosed bodies at hypersonic flight speeds: (a) thermodynamic equilibrium, in which the chemical reaction rates are "very fast" compared with the rates of diffusion across streamlines; (b) diffusion as rate-governing, in which the volume recombination rates within the boundary layer are "very slow" compared with diffusion rates across streamlines.

The material is developed by presenting the basic equations for heat transfer by conduction and diffusion, continuity, conservation of momentum, conservation of energy, and equation of state. These equations are solved by assuming "similarity" exists and then by determining the conditions (if any) under which this assumption is justified.

Paper makes considerable mathematical demands upon the reader; although, for the topic treated, this should not be unexpected.

Author finds that the maximum value of the ratio between heat transfer by diffusion alone and by heat conduction alone in the case of thermodynamic equilibrium is given by (*Prandtl no.*/*Schmidt no.*)$^{2/3}$, and states that more experimental work is necessary before one can accept these results.

W. A. Wolfe, Canada

3391. DeGroff, H. M., On viscous heating, *J. aero. Sci.* **23**, 4, 395–396 (Readers' Forum), Apr. 1956.

Author considers Couette flow of a viscous gas between two parallel planes, one of which is moving and one fixed. The planes are maintained at the same temperature, and viscous dissipation is taken into account. The viscosity and thermal conductivity are both assumed to be proportional to the absolute temperature, while the Prandtl number and the specific heat at constant pressure are both assumed to be constant. With these assumptions, the velocity and temperature distributions are derived, the formal solutions being similar to those obtained earlier by Illingworth [AMR **4**, Rev. 798] and by Tarapov [*Prikl. Mat. Mekh.* **19**, no. 3, Mar. 1955]. A detailed numerical analysis of the solution shows that, compared with the case of constant viscosity and thermal conductivity, the skin friction and heat transfer are increased, the heat transfer by a larger amount than the skin friction. Furthermore, the velocity profile is not a straight line, but is curved with a point of inflection and is consequently of an unstable type.

Probably due to a printing error, it is stated as a condition of the validity of the given solution that the fluid must be incompressible; however, in the paper cited, Illingworth showed that the solution is valid also for compressible flow.

J. T. Stuart, England

3392. Miller, A. P., and Moulton, R. W., Heat transfer to liquid-solid suspensions in turbulent flow in pipes, *Trend Engng. Univ. Wash.* **8**, 2, 15–21, Apr. 1956.

Experiments with water-graphite suspensions (5.85–13.5 wt %) and a 4.73 wt % kerosene-graphite suspension in turbulent flow inside a one-in. tube provided film heat-transfer coefficients using Wilson plot method.

Dittus-Boelter type of correlation proved very satisfactory for these data and data from other suspensions. All data were represented within 15% by using apparent viscosity of suspension.

$$Nu = 0.029\ Re^{0.8}\ Pr^{0.4}$$

average specific heats by weight, and thermal conductivity of suspending medium, all at bulk temperature.

Reviewer believes extension of this correlation to pseudoplastic suspensions to be significant.

A. Sesonske, USA

3393. Sibulkin, M., Heat transfer to an incompressible turbulent boundary layer and estimation of heat-transfer coefficients at supersonic nozzle throats, *J. aero. Sci.* **23**, 2, 162–172, Feb. 1956.

A calculation method for an approximate solution for heat transfer to an axisymetric turbulent boundary layer with arbitrary free-stream velocity and surface temperature distribution by means of the Karman integral method is presented for incompressible, constant property flow wherein the boundary-layer velocity profiles, total-temperature profiles, and skin-friction coefficient are considered independent of the pressure distribution. The turbulent velocity profiles were assumed to vary in accordance with the seventh power law and the wall shear stress distribution was assumed to be in accordance with the Blasius results for turbulent pipe flow. A modified form of the Reynolds analogy was used to relate skin friction and heat transfer. Some solutions are indicated for special variations of the free-stream velocity and surface temperatures. The calculated results present flow and thermal parameters for a particular nozzle.

These results are similar to those obtained by other investigators, notably D. R. Bartz [AMR **9**, Rev. 894] in a similar paper.

R. M. Drake, Jr., USA

3394. Schneider, P. J., Effect of axial fluid conduction on heat transfer in the entrance regions of parallel plates and tubes, 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prepr. no. 4, 17 pp.

A comparison between solutions omitting and including axial heat conduction is presented for uniform velocity flow and several thermal boundary conditions. M. Tribus, USA

3395. Sleicher, C. A., Jr., and Tribus, M., Heat transfer in a pipe with turbulent flow and arbitrary wall-temperature distribution, 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prepr. No. 5, 20 pp.

Paper is a summary of Sleicher's Ph.D. dissertation (Ch. E. Dept., Univ. of Michigan, 1955). Calculation of heat transfer in tubes by the eddy diffusivity concept is reviewed, including solution for arbitrary wall-temperature or heat-flux cases from the uniform wall-temperature solution.

The radial diffusivity equation was integrated on an electronic analog computer (type unstated) with a function generator to apply the local velocity distribution and eddy diffusivity distribution. Published velocity distributions agree sufficiently well among themselves. Eddy diffusivity was computed from the velocity distribution by von Karman's relation, using Jenkins' theoretical ratio α of the heat and momentum diffusivities, multiplied by the ratio of Sleicher's empirical α for air to Jenkins' theoretical α for air. Plots are given for Reynolds numbers of 6000 to 700,000 and Prandtl numbers of 0 to 7.5 of the constants needed in series solutions. The specific relations for linear wall temperature are also given.

Calculated results agreed within 2% with the known parabolic and plug flow cases. Recommended relations for Prandtl no. < 0.05 in long tubes are:

Uniform wall temperature: $Nu = 4.8 - 0.0150\ Pe^{0.91}\ Pr^{0.30}$

Uniform wall heat flux: $Nu = 6.3 - 0.0160\ Pe^{0.91}\ Pr^{0.30}$

C. F. Bonilla, USA

3396. Yuan, S. W., and Finkelstein, A. B., Heat transfer of a laminar pipe flow with coolant injection, 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prepr. no. 6, 10 pp.

A constant property fluid flows in laminar motion in a round pipe with constant rate of mass addition through the walls. At 1955 HTFMI, hydrodynamic solution was presented. Present paper considers solution to energy equation.

This reviewer believes that problem solved in this paper and in previous one is that of flow in a cylinder, closed at one end, and with fluid admission only from walls. Whether this solution is a good approximation to the case stated to be of interest in the paper remains unclear. M. Tribus, USA

3397. Fritzsche, A. F., Heat transfer in liquid metal (in German), *Forsch. Geb. Ing.-Wes.* **22**, 1, 33-35, 1956.

Paper is a brief report on measurements of forced and free convection in liquid metals done at the Academy of Sciences in the USSR. Heat transfer with the metals Hg, Sn, Pb, Bi, and Na as well as with alloys of Bi-Pb and Na-K has been investigated in laminar or turbulent flows of 0.1 to 20 m/sec within tubes of different size and cross section. In all cases the measured data may be represented by the empiric law: $Nu = A_1 + A_2\ Gr^m \cdot Pr^n$, where Nu is Nusselt number, A_1 and A_2 constants ($A_1 \geq 0$, $A_2 > 0$), m and n also constants or functions slowly varying with Gr (Grashof number) or Pr (Prandtl number). The results agree well with known data of heat transfer in air, water, water vapors, oil, and other organic liquids. M. Herbeck, Germany

3398. Livingood, J. N. B., and Donoughe, P. L., Summary of laminar-boundary-layer solutions for wedge-type flow over convection— and transpiration-cooled surfaces, *NACA TN* 3588, 33 pp., Dec. 1955.

A summary of exact solutions of the laminar-boundary-layer equations for wedge-type flow, useful in estimating heat transfer to such arbitrarily shaped bodies as turbine blades, is presented. The solutions are determined for small Mach numbers and a Prandtl number at the wall of 0.7; ranges of mainstream pressure gradients and rates of coolant flow through a porous wall are considered for the following cases: (1) Small temperature changes in the boundary layer along a constant—and along a variable-temperature wall, and (2) large temperature changes in the boundary layer along a constant-temperature wall.

Dimensionless forms of heat-transfer and friction parameters and boundary-layer thicknesses are tabulated. The results indicate that coolant emission and increased stream-to-wall temperature ratios diminished the friction and heat transfer for a constant wall temperature. For a variable wall temperature with small temperature differences in the boundary layer, the friction was unaffected, but the heat transfer was greatly increased for increased wall-temperature gradient. Heat-transfer results in the literature reveal that transpiration cooling is much more effective for Prandtl numbers of the order of 5.0 than for 0.7.

From authors' summary by C.-S. Yih, USA

3399. Mukhlenov, I. P., and Tumarkina, E. S., Heat transfer in a foam apparatus, *J. appl. Chem. USSR* **28**, 2, 125-132, Feb. 1955.

Article concerns results of research into heat exchange between water and air in direct mixture in a layer of mobile foam created on the grating of a foam apparatus, already described [Pozin, M. E., Mukhlenov, I. P., Tumarkina, E. S., and Tarat, E. Y., title source, **27**, 1, Jan. 1954].

The rate at which the processes of heat and mass transfer occur during foam contact between liquid and gas considerably exceeds the intensity of mass and heat loss in existing heat-exchange apparatus.

The general coefficient of heat transfer, K_T, (in cal/hr/m^2/C) and the coefficient of mass transfer, β_x, (in kg/m^2/hr) increase with rise in gas velocity across the full cross section of the foam apparatus, due to the increase in thickness and turbulence of foam thus obtained. At gas velocities u between 1 and 3.5cm/sec and at about 15-mm height for the initial layer of water from which foam forms upon admission of air,

$$K_T = 4460 + 620\ u^{2.4}$$

A. E. Brun, France

3400. Mukhlenov, I. P., and Tumarkina, E. S., Heat transfer in a foam apparatus, *J. appl. Chem. USSR* **28**, 4, 323-329, Apr. 1955.

In the previous article [see preceding review], the effect of gas-flow rate upon heat-transfer coefficient K_T was investigated. Here the effect of the thickness of the initial layer of liquid (h_o in mm) is examined. An increase in h_o results in an increase in K_T, the relationship being linear, for an h_o between 10 and 30 mm, and at various air-flow rates. K_T is directly proportional to the thickness of the layer of foam H over the grating, within the H interval from 80 to 400 mm.

The efficiency of a tray of the foam apparatus (η in %) is defined as the ratio of the actual difference in heat content of the air upon the entrance and at exit to the difference in heat content of the entering air and air saturated with moisture at the average temperature of the water in the tray for an h_o ranging from 8 to 35 mm, approximately $\eta = 59 + h_o$. Also, η increases directly with foam thickness according to the relation $\eta = a'H^n + b'$, the values of a', b', and n having been found experimentally for various rates of gas flow.

Authors conclude that a foam apparatus would be most suitable to processes involving heat exchange by direct contact of liquid and gas. A. E. Brun, France

3401. Czarnecki, K. R., and Sinclair, A. R., An investigation of the effects of heat transfer on boundary-layer transition on a parabolic body of revolution (NACA RM-10) at a Mach number of 1.61, *NACA Rep.* 1240, 11 pp., 1955.

See AMR **8,** Revs. 1086 and 1087.

3402. Durfee, W. H., Heat flow in a fluid with eddying flow, *J. aero. Sci.* **23,** 2, 188-189 (Readers' Forum), Feb. 1956.

3403. Hartshorn, A. S., and Nicholson, L. F., The aerodynamics of the cooling of aircraft reciprocating engines, *Aero. Res. Counc. Lond. Rep. Mem.* 2498, 135 pp., 1956.

3404. Dropkin, D., and Carmi, A., Natural convection heat transfer from a horizontal cylinder rotating in air, 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prepr. no. 10, 22 pp.

The results of the investigation reported in this paper lead to the following conclusions:

1. When a heated cylinder is rotated in air, the heat-transfer coefficient may be located in one of three distinct regions: (a) in a region where its value does not change with speed of rotation; (b) in a region where its value increases with the speed of rotation and is influenced by both speed and free convection; (c) and a region where its value is proportional only to the speed of rotation.

2. Within the limits of temperatures used in the tests and for Reynolds numbers larger than 15,000, the heat-transfer coefficients may be computed from

$$Nu = 0.073(Re)^{0.7}$$

3. The entire region in which the heat-transfer coefficient is influenced by rotation may be expressed by equation

$$Nu = 0.095(0.5\ Re^2 + Gr)^{0.35}$$

From authors' summary

3405. Kapadnis, D. G., The effect of fluid motion on heat transmission. Part II, Solids of different shapes and sizes, *Indian J. Phys.* **29,** 6, 296–308, June 1955.

A detailed experimental study of the effect of a unidirectional stream of air on the rate of heat dissipation from solids of different shapes and sizes by forced convection has been made in a limited range of Reynolds numbers from 10^3 to 10^5. The experimentally derived values of the constants B and n in the Nusselt equation (employed for air)

$$(1/A\,\Delta\theta)(dQ/dT)(D/K) = B(VD/\xi)^n$$

are, respectively, 0.505 and 0.516 for horizontal cylinders with ellipsoidal nosepiece, 0.033 and 0.783 for the same with plane blunt nose-piece; 0.78 and 0.517 for spheres; 0.12 and 0.654 for rectangular parallelopipeds placed in face-on position; and 0.24 and 0.576 for the same placed in edge-on position. Finally, the experimental data are compared with those of other investigators.

From author's summary

3406. Bowden, D. T., Effect of pneumatic de-icers and ice formations on aerodynamic characteristics of an airfoil, *NACA TN* 3564, 59 pp., Feb. 1956.

Measurements of lift, drag, and pitching moment of an NACA 0011 airfoil were made in icing using two types of pneumatic de-icers, one having spanwise inflatable tubes and the other having chordwise tubes. Ice remaining after inflation of the spanwise-tube de-icer increased airfoil section drag 7 to 37% for 0° to 4.6° angle of attack over the ranges of air speed, total air temperature, liquid-water content, and cycle times covered. This drag increase became constant after a few de-icing cycles. Drag increases due to ice remaining on the chordwise-tube de-icer were similar to those for the spanwise-tube de-icer. Minimum airfoil drag in icing (averaged over a de-icing cycle) was usually obtained with a short (about 1 min) de-icing cycle.

Alternate tube inflation was normally used, whereby every other tube was inflated and deflated, followed by inflation and deflation of the remaining tubes. In dry air, alternate inflation of the spanwise boot increased airfoil drag (averaged over a 1-min cycle) by 10 to 16%. Simultaneous tube inflation reduced the 10% increase to 3.2%. Inflating the chordwise boot had a negligible effect on average airfoil drag.

With the de-icer inoperative, rime-ice formations of 0.5 pound per foot span increased airfoil section drag 38 to 67% and decreased lift up to 4% for 0° to 4.6° angle of attack. The same amount of ridge-type glaze ice increased drag 124 to 230% and decreased lift up to 20% for 0° to 9.3° angle of attack. To help determine the effect of size and location of ridge-type ice formations on drag, spanwise spoilers were mounted on the bare airfoil at various chordwise positions. From these data, the drag increase was found to vary almost directly with spoiler height and the local air velocity over the bare airfoil.

From author's summary

3407. Linahan, T. C., The dynamic response of industrial thermometers in wells, *Trans. ASME* **78,** 4, 759–763, May 1956.

Paper extends previous work on step- and frequency-response curves of sheathed thermometers. McAdams heat-transfer formulas give good agreement with experiment for flow normal to thermometer axis; for random flow, film resistance can be determined by measuring a first-order time constant and dividing by computed heat capacity. N. Ream, England

3408. Paynter, H. M., and Takahashi, Y., A new method of evaluating dynamic response of counterflow and parallel-flow heat exchangers, *Trans. ASME* **78,** 4, 749–758, May 1956.

Response of heat exchanger with constant heat-transfer coefficients and no axial heat flow involves seven dimensionless parameters. Laplace transforms are obtained for parallel- and counterflow; the exact transform is approximated by a standard form by a method due to Paynter but not yet published (it is related to characteristic-function method of statistics). This gives quantitative comparison of responses. Several special cases are compared with experiment. Method should be valuable in studying other chemical plant dynamics.

N. Ream, England

3409. Galbiati, A., Charts for rapid calculations of shell and tube heat exchanger, (in Italian), *Termotecnica* **10,** 1, 7–14, Jan. 1956.

3410. Kopal, Z., Physics of the sun, *Brit. J. appl. Phys.* **7,** 4, 119–128, Apr. 1956.

The first part of this highly informative paper reviews fundamental observed data on the physics of the sun. The second part outlines the equilibrium model of the solar interior, showing that the forces are primarily gravitational and that most of its interior is probably in radiative equilibrium. The third part reviews the principal nuclear reactions capable of transforming hydrogen into helium under conditions prevailing in the solar interior. The concluding section reviews the physics and chemistry of the solar visible surface and of its atmosphere, and also describes the solar corona. A. Whillier, South Africa

3411. Trombe, F., and Foëx, M., On refrigeration using solar energy as a heat source (in French), *C. R. Acad. Sci. Paris* **242,** 8, 1000–1003, Feb. 1956.

A modified ammonia absorption refrigerator for producing ice is described. System might be of interest in hot dry climates where there is daily sunshine. Tests carried out at the Mt. Louis Solar

Laboratory indicate that 1 kg of ice could be produced per kWh of incident solar energy using a cylindrical-paraboloidal reflector to collect solar energy at 90C, provided that the condenser could be kept below 25C.

Reviewer believes that since a 25C condenser temperature cannot be attained in hot climates without use of cooling water (which is usually scarce), in practice a collector temperature considerably higher than 90C would be needed, and the specific output of ice might decrease significantly. System does show promise, however, and seems to be better than classical absorption refrigeration systems. A. Whillier, South Africa

3412. Dunkle, R. V., and Bevans, J. T., An approximate analysis of the solar reflectance and transmittance of a snow cover, *J. Meteor.* **13,** 2, 212–216, Apr. 1956.

The transmittance and reflectance of a snow cover has been analyzed by use of the model of a diffusing medium introduced by Schuster. The general case of a slab of finite thickness, irradiated from both sides, is solved and reduced to the case of a semi-infinite slab irradiated from one direction, as an approximation of the radiative component of energy flow in a deep snow cover. The transmission factor of interest for heat transfer within the medium is shown to be different from that obtained experimentally. From authors' summary

3413. Suomi, V. E., Franssila, M., and Islitzer, N. F., An improved net-radiation instrument, *J. Meteor.* **11,** 4, 276–282, Aug. 1954.

An improved net-radiation instrument for measuring the net flux of radiant energy through a surface parallel to the earth's surface, which employs the principle of exposing a ventilated radiation-absorbing element to the radiation sources, is described. The importance of providing similar ventilation on both sides of the absorbing plate is pointed out, and the control features to insure this uniformity are described. A method of reducing the error due to the variation of the absorptivity of the blackened surface with wave length is discussed. The performance of the instrument and the possible errors are described.

It was found that the instrument is capable of giving net-radiation measurements accurate to within 2%.

From authors' summary

3414. Owen, P. R., and Ormerod, A. O., Evaporation from the surface of a body in an airstream (with particular reference to the chemical method of indicating boundary-layer transition), *Aero. Res. Counc. Lond. Rep. Mem.* 2875, 42 pp., 1954.

The problem of predicting the rate of transport of a gas from or into the surface of a two-dimensional body in an airstream is discussed. The principal object of the investigation is to provide a means of estimating the time required to obtain an experimental record of boundary-layer transition when a chemical technique is used. The methods evolved should, however, find an application to other forced diffusion phenomena.

The general approach is based on the analogy between mass transfer, heat transfer, and skin friction, and the analysis is applied to both a laminar and a turbulent boundary layer on the surface of the body; it also includes the problem of diffusion commencing in an established boundary layer. For this problem, an approximate, alternative solution to that of O. G. Sutton, for a turbulent boundary layer, is given.

Particular attention is paid to a description of the boundary condition at the surface of the body, and it is concluded that, for evaporation, the usual assumption that the air is saturated with the diffusing substance is, in general, satisfactory.

The influence of molecular diffusion on the transfer of a gas through a turbulent boundary layer is considered; it is demonstrated that the effects of molecular diffusion in the laminar sublayer may be important. A simple, approximate method of estimating the molecular diffusion coefficient for a pair of gases is derived.

A description is given of a wind-tunnel experiment in which measurements were made of the rates of sublimation of some chemicals from a small part of a flat plate with a turbulent boundary layer; they were found to agree fairly well with the corresponding theoretical estimates.

Finally, as an example of the application of the methods, a calculation of the effect of altitude on the rate of sublimation of a chemical from the surface of an aircraft is made; this agrees with flight tests, which had established that the rate of sublimation decreases very rapidly with increase of altitude.

From authors' summary

Combustion

(See also Revs. 3257, 3348)

3415. Giddings, J. C., and Hirschfelder, J. O., Flame properties and the kinetics of chain-branching reactions, *Univ. Wisc. Nav. Res. Lab.* (8) SQUID-5, 31 pp., May 1956.

Authors present calculations of flame velocity and temperature/concentration profiles for flames maintained by a simple chain-branching reaction with second-order termination. The differential continuity equations are solved by Klein's integral equation method [*Univ. Wisc. Nav. Res. Lab.* (8) SQUID 1 and 2, Feb. 1955] assuming as first approximation the Bodenstein stationary state for the radical concentration. The chemical kinetic constants used approximate possible reaction steps in $H_2/0_2$ reaction: E (branching) = 10 kcal/mole, E (termination) = 0, equal pre-exponential factors. The results show that the stationary state is a good approximation and that the over-all reaction is equivalent to a simple second-order one with E = 20 kcal/mole. The value of 58.3 cm/sec given for the flame velocity at a flame temperature of 3000K appears to reviewer to be about a power of ten less than that expected for the parameters given in the text.

Authors present a criterion for the applicability of the stationary-state hypothesis in flames based on the relative reaction times of the radical and of the over-all reaction. They discuss semiempirical theories based on radical diffusion from flame products in chemical equilibrium and conclude that in none of the cases studied by them, including those where the stationary state does not apply, do the results support such theories. Reviewer believes this and previous reports in this series to be an important contribution to the understanding of flame propagation and reaction kinetics. They show the problems of flames propagated by chain reactions to be similar qualitatively to those of the well-understood single reaction case. However, much remains to be done before these methods are applicable to quantitative technical problems in combustion engineering. G. K. Adams, England

3416. Sanger-Bredt, I., Investigation into the initial steps of combustion processes (in German) *Astronaut. Acta* **1,** 1, 1–31, 1955.

Historical development of our knowledge of molecular reactions is traced through the law of mass action and the study of chemical equilibria. This route is contrasted with investigations of nuclear reactions which began as the study of individual collisions. Techniques, which have been used to study reactions in flames, in particular spectroscopic techniques, are reviewed and their limitations discussed. Finally, a crossed molecular beam method to study single steps in combustion reactions is shown to be feasible if a source of free radicals at a pressure of 10^{-3} mm is available.

From author's summary by D. M. Simon, USA

3417. Michner, M., and Gross, R. A., Effect of radioactivity and corona discharge on flame stabilization, *J. aero. Sci.* **23,** 6, 607–608 (Readers' Forum), June 1956.

3418. Rogers, D. E., and Marble, F. E., A mechanism for high-frequency oscillation in ramjet combustors and afterburners, *Jet Propulsion* **26,** 6, 456–462, June 1956.

Paper deals with the phenomenon of screeching combustion instability in ramjets and afterburners characterized by its relatively high and extremely regular frequency and by the fact that the sustaining mechanism is not associated with periodic fluctuations in fuel-injection or air-flow rates. Experimental investigation is made of the behavior of a small two-dimensional combustion chamber, burning a uniform mixture of air and fuel vapor under conditions of high-frequency oscillations. Measurements are made of the limits of stable screech, the amplitude and frequency of pressure oscillations over a wide range of mixture ratio, inlet air temperature, and combustor flow rate. Spark schlieren photographs and high-speed motion pictures taken of the combustion process showed, in agreement with other investigations, that the high-frequency oscillation is accompanied by vortexes shed periodically from the flameholder lip with the same frequency as the oscillation.

Mechanism of excitation of these oscillations is suggested.

From authors' summary by P. Laffitte, France

3419. Emmons, H. W., The film combustion of liquid fuel, *ZAMM* **36,** 1/2, 60–71, Jan./Feb. 1956.

The rate of combustion C_0 of a larger droplet of liquid fuel ($> 10^{-1}$ in.) is mainly governed by the rate of heat and mass transfer in boundary layer. In the equations expressing momentum, energy, and mass within this layer an energy variable b = (*enthalpy*) + (*potential chemical heat release*) becomes a linear function of the velocity u along the surface, if an assumption (*Prandtl number*) = (*Schmidt number*) = 1 may be admitted. U may thus be worked out assuming (*density*) × (*viscosity*) = *const.* If heat ratio is defined as B = (*thermal energy of unit mass of main stream*)/(*thermal energy at surface to put unit mass of fuel into the boundary layer*), C_0 may be expressed as $C_0 = B \times$ (*friction coefficient*)/2. Exact and approximate numerical solutions gave excellent agreement with recent experimental data and with empirical formula. The maximum value of C_0 exists at $B = \infty$, where $C_0 \times$ (*Reynolds number*)$^{-1/2} = 1.2386$.

Reviewer thinks that some drastic assumptions should be inevitably introduced for carrying out such an exact mathematical-physical analysis. As this, certainly, is one of the necessary courses of advance in the field of investigations on combustion, this paper may be regarded as a good guide post. Paper contains a small number of misprints [Eqs. (19) (55)], although they have no influence of its real value. I. Sawai, Japan

3420. Miesse, C. C., The combustion of atomized liquid propellants, Amer. Chem. Soc. Prepr., 129th Ann. Meet., Dallas, Tex., Apr. 1956, 29 pp. + 16 figs.

The applicable theoretical and experimental papers on atomization, evaporation, and combustion of liquid propellants are summarized and applied to the problem of the combustion of atomized liquid propellants. The available reports on ignition delay, performance, and stability limits for liquid-propellant combustors are then reviewed, and the data correlated in accordance with the experimental data and theoretical concepts summarized above. The results of the survey indicate that more rapid ignition, higher performance, and lower stability limits are achieved by fine atomization, and that the effects of unstable combustion and erosive burnout of combustion chamber walls are minimized by coarser atomization. Several atomization criteria for optimum performance are proposed as a consequence of this investigation.

Conclusions: The established correlations and laws of atomization and evaporation are directly applicable to the various combustion problems of ignition delay, performance, stability limits, and design. Experimental and theoretical information obtained from a study of the single droplet are of great value in understanding the behavior of sprays, and the combustion of sprays in general. Ignition delay, performance, and stability limits can all be considered with respect to the quantity of vapor available for combustion, and can, therefore, be explained in terms of the initial atomization and subsequent evaporation of the liquid propellants. The limited quantity of precise knowledge in this important field should serve to stimulate an extended investigation of the phenomena involved. K. J. DeJuhasz, Germany

3421. Shapiro, A. H., and Erickson, A. J., On the changing size spectrum of particle clouds undergoing evaporation, combustion, or acceleration, 1956 Heat Transfer and Fluid Mechanics Institute, Stanford, Cal., Prepr. no. 8, 30 pp.

Many industrial processes require that a cloud of solid particles or liquid droplets interact with the gaseous (or, sometimes, liquid) phase in which they are dispersed. In certain of these processes there is a spectrum of particle sizes, and moreover, the particles change in size by reason of interaction. Examples include: (a) evaporation of a cloud of liquid droplets; (b) growth of a liquid cloud by condensation; (c) combustion of either solid fuel particles or liquid fuel droplets. Normally the rate of growth (in an algebraic sense) of each particle will depend, among other things, on the diameter of the particle itself. Under such conditions the shape of the particle spectrum will change as time proceeds, and this naturally introduces difficulty into the analysis of the problem. Even when there is no change in particle size, the spectral distribution of sizes may change; e.g., if the cloud is accelerated, different sizes of particles will accelerate at different rates, and the differences in particle speeds will alter the relative concentrations per unit volume of the several particle sizes.

A theoretical treatment is given showing how the size distribution of a cloud of particles changes as a result of evaporation, combustion, or acceleration. The general differential equation governing the concentration of particles as a function of size, position, and time is formulated for one-dimensional duct-type flows. Solutions to the differential equation are then obtained for a number of special problems of interest to evaporation and combustion.

If the process depends mainly on molecular transfers (i.e., at very low Reynolds numbers), the equivalent mean diameter for evaporation or combustion of drops is found to be approximately constant with time. This suggests that the conventional model of a constant number of uniform drops of varying size be replaced by a new model having a varying number of uniform drops of constant size. The new model predicts a lower rate of evaporation or combustion than the conventional model.

K. J. DeJuhasz, Germany

3422. Barrère, M., and Moutet, H., Experimental study of the combustion of monergol drops (in French), *Rech. aero.* no. 50, 31–38, 1956.

The evolution of monergol drop diameter during combustion is studied. Two types of monergols have been used: (1) those where fuel and oxidizer belong to the same molecule, such as ethyl nitrate, propyl nitrate, hydrogen peroxide; and (2) those where fuel and oxidizer are mixed liquids, such as organic acetates in nitric acid.

Square of drop diameter varies in each case linearly with time, and the slope of this curve is determined as a function of nature and temperature of the medium surrounding the drop. This slope defines a combustion constant which is characteristic of the monergols used and of the test conditions but independent of the drop diameter. This constant varies with the nature and tempera-

re of the ambient medium; it increases in air for fuel-poor mixres and finally becomes less reliable if temperature around the op reaches over 1000C. R. Delbourgo, France

3423. Kuhlmann, A., A new nozzle construction for burning heating oil and powdered coal (in German), *ZVDI* **98**, 15, 837–839, 1956.

A new nozzle design has been developed, characterized by complete, smokeless combustion at low air consumption. The essential element is a mixing distributor for the combustion air which divides the feed air into numerous separate streams and directs these against the fuel stream in such a manner that thorough mixing with the fuel spray takes place in the burner itself. It is suitable for gas, heating fuel oil, and for powdered coal. A combination of fuels can be used; e.g., by using fuel oil and a combustion air enriched by powdered coal. K. J. DeJuhasz, Germany

3424. Strong, H. M., and Bundy, F. P., Measurement of temperatures in flames of complex structure by resonance line radiation; I. General theory and application to sodium line reversal methods; II. Sodium line reversal by high-resolution spectroscopy; III. From absolute intensity measurements at high resolution, *J. appl. Phys.* **25**, 12, 1521–1537, Dec. 1954.

3425. Glinkov, M. A., and Zen'kovskiĭ, A. G., Investigation of the external heat exchange in furnaces by means of experiments (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 11, 108–123, Nov. 1954.

Acoustics

(See also Revs. 3183, 3299, 3346)

Book—**3426. Fischer, F. A., Fundamentals of electroacoustics,** (Translated by S. Ehrlich and F. Pordes), New York, Interscience Publishers, Inc., 1955, xii + 186 pp. $6.

Book is the outgrowth of lectures given by the author, who has directed electroacoustical laboratories in industry and government service, to his younger colleagues (physicists and electronic engineers) to enable them to work in electroacoustics more or less independently as soon as possible. The presupposed knowledge is reduced to a minimum: simple rules of differential and integral calculus, fundamental laws of the general theory of oscillations and alternating currents and acoustics. The textbook is focused on electroacoustic transducers, especially their theoretical foundations and technical applications; experimental methods are only touched upon.

The first chapter introduces the laws of the electric and mechanical oscillators with regard to their reciprocity and duality whereby the theory is restricted to linear problems. The following chapters contain: Forces exerted on matter by electric and magnetic fields, electroacoustic energy conversion principles, differential equations, impedance, efficiency and sensitivity of transducers; furthermore, radiation of sound, broad-band transducers and electromechanical coupling. The last chapter closes with a short qualitative report on conversion in electric resistances (hot-wire and contact microphone).

Reviewer recommends the book as an introductory work, since it is very clearly written and the boundaries of the approximations used for practical reasons are always well exposed.

M. Herbeck, Germany

3427. Klein, B., Fundamental frequencies of arbitrarily shaped simply-supported triangular plates, *J. roy. aero. Soc.* **60**, 541, 63–64 (Technical Notes), Jan. 1956.

3428. Westphal, W., Flexural waves in a plate and sound radiation (in German), *Akust. Beihefte* no. 2, 603–610, 1954.

The relation between the flexural waves in a plate and the sound radiation, as well as the directional distribution of the radiation, have been studied both theoretically and experimentally. The radiation is characterized by the "radiation coefficient" s. Above the critical frequency of the plates this coefficient is about one. Below the critical frequency, s decreases with decreasing frequency; however, in the case of vibrations forced by airborne sound less than for "free" flexural waves. The slope of decrease depends on the dimensions and the damping of the plates. By means of the radiation coefficient s, which is roughly known, one can estimate the sound energy radiated of the plate, after having measured the amplitude of the flexural vibrations. With that it is possible to determine directly the flanking transmission in building acoustics. From author's summary

3429. Andreev, N. N., On second-order quantities in acoustics (in Russian), *Akust. Zh.* **1**, 1, 3–11, 1955 (Translated from Russian by M. D. Friedman, 572 California St., Newtonville 60, Mass.)

Questions of the density and flow of audio energy, and of the momentum and pressure of audio radiation, are considered in this work. The methods of first- and second-order successive approximations are the basis of the reasoning, where the necessity of clearly differentiating the Lagrange and Euler points of view are taken into account.

An explanation is given of the fact that the usual viewpoint on the density and flow of audio energy and the viewpoint explained in the present work are opposite. It is shown that the total solution of the problem depends on taking the boundary conditions into account. The particular example explained at the end illustrates the statements made in this work.

From author's summary

3430. Lippert, W. K. R., Wave transmission around bends of different angles in rectangular ducts, *Acustica* **5**, 5, 274–278, 1955.

The characteristic reflection and transmission factors of bends of various angles in rectangular tubes have been measured for plane waves by using the technique of the nonreflecting output duct. The frequency characteristics for angles greater than 90° give complex curves which show a systematic change with increasing angle. Altering the shape of a bend had a great effect on the values of the characteristic factors; this is shown experimentally with a rounded right-angled bend. The propagation of plane waves around the various bends is completely specified by the measured magnitude and phase values of the characteristic factors. These provide a set of basic characteristics for designing acoustical filters. From author's summary

3431. Zwicker, E., and Feldtkeller, R., Loudness of uniform noises (in German), *Acustica* **5**, 6, 303–316, 1955.

With the aid of equal loudness contours (loudness in sones as parameter), of the measured width of the frequency groups and reduction of loudness in neighboring frequency groups, the level of sustained noises with given spectra can be calculated. The aural analysis of a sound into bands of definite size (frequency groups), already demonstrated in respect to hearing threshold, masking and phase detection, appears meaningful in the investigation of noise levels. Loudness is estimated from the sound intensity in the frequency groups, acting separately at low intensities but with considerable throttling of one group by neighboring ones at high intensities. From authors' summary

3432. Lyon, R. H., Propagation of correlation functions in continuous media, *J. acoust. Soc. Amer.* **28**, 1, 76–79, Jan. 1956.

The correlation properties of noise fields when considered as a random superposition of elementary sources are derived as an extension of Rice's work on the shot effect [S. O. Rice, *Bell Syst. tech. J.* **23**, p. 282, 1944; **24**, p. 46, 1945]. Next, a formalism is derived which calculates the correlation properties of the response

of a continuous linear system when subject to an applied noise field. The requirements for solution are a knowledge of the impulse response of the system and the correlation function of the source. The latter may be obtained experimentally or from calculation. From author's summary

3433. Robey, D. H., On the contribution of a contained viscous liquid to the acoustic impedance of a radially vibrating tube, *J. acoust. Soc. Amer.* **27**, 1, 22–25, Jan. 1955.

The impedance presented to the inside surface of a hollow, liquid filled, radial cylinder of finite length has been determined theoretically. It was assumed that the liquid was retained by pressure-release caps or one pressure-release cap and one rigid cap at each end. For a loss-free liquid it is shown that the reactance presented to the cylinder wall becomes infinite whenever the liquid has a longitudinal or coupled radial resonance.

A sizeable resistance may appear when a viscous liquid is used. This is because the geometry of the arrangement is ideal for creating large shear losses. Exceptions to this occur for high frequencies where the wave length is small in comparison to the cylinder length. From author's summary

3434. Helberg, H. W., Velocity of sound in narrow rigid tubes (in German), *Acustica* **5**, 5, 267–268, 1955.

This note gives graphs showing the attenuation constant and wave velocity for a fluid in which viscosity plays the controlling part. Heat conduction is neglected. The problems considered are two parallel planes a distance a apart and a circular tube of diameter d. These lengths are assumed to be small compared with the wave length of the sound.

Only a short summary of the results is given, but the graphs may be of use to workers in this field.

J. M. Jackson, Scotland

3435. Venkatasubramanian, V. S., Sound velocity in a Lennard-Jones liquid model, *J. Indian Inst. Sci.* (A) **37**, 4, 227–231, Oct. 1955.

Making use of the partition function derived by Lennard-Jones for a plausible model of a liquid, an expression for sound velocity is derived. This is applied to discuss some features regarding the dependence of velocity on chemical constitution and to calculate the ultrasonic velocities in liquid gases for which the requisite data are available. There is fair agreement with experimental values. From author's summary

3436. Busby, J., and Richardson, E. G., The propagation of ultrasonics in suspensions of particles in a liquid, *Proc. phys. Soc. Lond* (3) **69**, 434, 193-202, Feb. 1956.

The propagation of sound in suspensions of solid particles in water in the range of frequency 1 to 10 Mc/s and of particle radius 8 to 100 microns is measured. For the ultrasonic attenuation, a pulse method is used, and the suspension is either monodisperse (glass spheres) or polydisperse (silica particles). In the latter suspension, the particle-size distribution is measured optically.

Results are compared with a theory due to Sewell and others and good agreement is obtained. The ultrasonic absorption is linear with concentration up to 18% by volume. Some measurements were also made on "sediments" of glass spheres and natural sands in which the attenuation is high and increases rapidly with frequency and particle size. From authors' summary

3437. Junger, M. C., Sound propagation in a fluid-filled tube with massive wall reactance, *J. acoust. Soc. Amer.* 28, 2, 165–167, Mar. 1956.

The results of an experimental study of a relatively unfamiliar mode of propagation are presented: the zero-order mode in a tube with massive wall reactance. The observed and theoretical dispersion curves, which show good agreement, display a high-pass cut-off frequency. There is a dead zone between this frequency and the ring resonant frequency of the tube.

The phase velocities c_z are measured indirectly from the directivity patterns of a receiver in the form of a long rubber hose coupled to a microphone; these patterns are characterized by two symmetrical lobes whose angular separation is $2 \cos^{-1} c/c_{z}$, c being the sound velocity. From author's summary

3438. Lawley, L. E., and Reed, R. D. C., A reverberation method for the measurement of the absorption of ultrasonics in liquids, *Acustica* **5**, 6, 316–322, 1955.

The ultrasonic reverberation of a liquid contained in a spherical vessel of about 0.5-litre volume has been investigated experimentally over the frequency range 200 kcps to 2 Mcps. The time constant of acoustic exponential decay was measured by a null method in which it was balanced against an exponential wave form of known time constant generated in an RC network. The mechanism of energy loss in the vessel was investigated and this loss was allowed for by calibration of the vessel, using a liquid of known absorption. The absorption was determined in a number of organic liquids and evidence of relaxation effects was observed in methyl benzoate, toluene, and acetaldehyde.

From authors' summary

3439. Mawardi, O. K., On thermoacoustic transduction in a potential flow, *J. acoust. Soc. Amer.* **28**, 2, 239–245, Mar. 1956.

Interaction between acoustic field and thermal field is analyzed for case of a sound wave propagating down a channel in which heat convection occurs in a potential flow. Analysis restricted to inviscid fluids shows that magnitude of sound wave is reinforced as it propagates through the thermal field. Extent of this reinforcement is given in the form of an amplification factor which depends on the parameter of the flow and on the frequency of the sound wave. From author's summary by S. Ostrach, USA

3440. Springer, A. M., An apparatus for the temporal lengthening and pick-up of tape records (in German), *Acustica* **5**, 5, 279–283, 1955.

Ballistics, Detonics (Explosions)

(See also Rev. 3251)

3441. Petersen, N. V., Lifetimes of satellites in near-circular and elliptic orbits, *Jet Propulsion* **26**, 5 (part I), 341–351, 368, May 1956.

Paper estimates the lifetime for a simple satellite configuration from an arbitrary initial near-circular or elliptic constraint at launch to decay to the surface of the earth. There is a discussion of the structure of the atmosphere and free-molecule flow drag. The nonlinear differential equations of motion for near-circular constraint are shown, but not solved. The equations are linearized by assuming that the path velocity does not vary appreciably for a small increment of altitude above the earth's center, and that variable altitude above the earth's center is a constant for small increments of time. A solution for the linear case is presented. Time increments for arbitrary altitude losses are approximated and total lifetime is obtained by summation of these increments.

Using a constant drag coefficient, a plot is given for circular orbits of satellite lifetime versus altitude. Similar results are presented for elliptic orbits. E. A. Trabant, USA

3442. Perkins, F. M., Flight mechanics of ascending satellite vehicles, *Jet Propulsion* **26**, 5 (part I), 352–358, May 1956.

Some phases of optimization of low-altitude continuous-thrust trajectories and high-altitude interrupted-thrust trajectories are

covered. Use is made of results and discussion from AMR **8**, Rev. 2014. Orbits of departure and arrival of interplanetary travel are considered with minimum energy requirements to achieve low-altitude orbit. Mention is made of analog computer trajectory calculations with a discussion of digital computer trajectory computations. To achieve a maximum vertical distance with a definite horizontal velocity at power cutoff, it is not required that the vertical velocity at power cutoff be zero. During the determination of the equation for optimum pitch angle it is assumed that a definite horizontal component of velocity must be achieved at power cutoff. Methods are presented for determining the unknown angles in the equation of optimum pitch angle for a continuous-thrust ascent trajectory. A three-stage interrupted-thrust trajectory is used as an example in the discussion of the optimization of this type of trajectory. E. A. Trabant, USA

3443. Reid, W. P., On the motion of a missile under water, *Jet Propulsion* **26**, 6, 463–464, June 1956.

Differential equations of motion of a missile are derived on the basis of certain simplifying assumptions initiated originally by others with the underwater motion of a missile in mind. Comments are made on the significance of these assumptions, and the analytical solution to the equations is developed.

From author's summary

Soil Mechanics, Seepage

(See Revs. 3232, 3270, 3453)

Micromeritics

(See also Rev. 3436)

3444. Miller, E. E., and Miller, R. D., Physical theory for capillary flow phenomena, *J. appl. Phys.* **27**, 4, 324–332, Apr. 1956.

Paper reviews problem of two-phase flow through porous media, with special mention of hysteresis effects due to interface behavior in irregular capillaries. Qualitative descriptions are given; fundamental equations derived; and dimensionless variables defined. Reviewer feels title is somewhat grandiose for an elementary dimensional treatment. However, paper seems to be free of errors and provides a good introduction to capillarity effects in porous media. R. R. Hughes, USA

3445. Hall, W. A., An analytical derivation of the Darcy equation, *Trans. Amer. geophys. Un.* **37**, 2, 185–188, Apr. 1956.

On the assumptions that: (1) inertia forces resulting from flow are negligible; (2) an elemental volume of fluid-porous-body system can be selected at any point such that it is small with respect to the gross dimensions of the system, yet large enough to possess uniformity of matrix surface area; and (3) that liquid films are continuous, author evolves analytically the Darcy equation expressing the fluid velocity in terms of the pressure and gravitational gradients. For nonisotropic porous media, results indicate the permeability to be a tensor, while for isotropic porous media the permeability is a scalar whose magnitude varies with time, position, and fluid content. S. R. Faris, USA

3446. Aronofsky, J. S., and Porter, J. D., Unsteady radial flow of gas through porous media—variable viscosity and compressibility, *J. appl. Mech.* **23**, 1, 128–132, Mar. 1956.

In transient flow of gas in disk-shaped porous bodies of uniform thickness, nonideal behavior of the gas is assumed to be characterized by linear relations between pressure and viscosity and pressure and density. The differential equation describing the flow system is reduced to a difference equation and solved digitally by the MIT computer Whirlwind. Computational procedure is essentially that outlined earlier by senior author [AMR **7**, Rev. 202]. Results indicate variable viscosity and density produce substantial effect on transient flow behavior of gas in porous media.

Dimensionless plots of pressure versus time succinctly summarize results of the study. S. R. Faris, USA

3447. Todd, D. K., Unsteady flow in porous media by means of a Hele-Shaw viscous fluid model, *Trans. Amer. geophys. Un.* **35**, 6, 905–916, Dec. 1954.

The problem of unsteady flow in porous media was investigated for the two-dimensional case by a model analogy consisting essentially of an oil flowing through a narrow glass channel. The apparatus, known as a Hele-Shaw viscous fluid model, avoided the difficulties of measuring flow in porous media. The model was calibrated by steady-flow measurements. Unsteady flows, composed of sudden releases of oil into and out of the channel, were recorded and analyzed. Results were presented in graphical form using dimensionless parameters. Agreement with numerical solutions of the basic nonlinear differential equation, as applied to gas flow through porous media, was obtained. A study of a series of solitary sine waves was made as a model analogy of the damping of a flood hydrograph in a ground-water table adjacent to a stream. Results indicated that the damping rate was independent of both amplitude and period of the flood wave and that the damping distance was a function of the period but not of the amplitude.

From author's summary

3448. Robinson, A., On the motion of small particles in a potential field of flow, *Comm. pure appl. Math.* **9**, 1, 69–84, Feb. 1956.

Author presents a rigorous derivation of the equations of motion of a continuous distribution of small particles in a flowing fluid. In particular, formulas are derived for the mass of particles deposited on an obstacle in the flow. It is assumed that the particles do not interfere with the fluid flow, that the drag force is proportional to the vector difference between particle velocity and fluid velocity, and that this difference is small. The method of theoretical attack employed by the author should be of interest to those concerned with problems of icing or of silting.

G. C. Wallick, USA

3449. Bouvard, M., A theoretical study of suspension regime in turbulent flow (in French), *Houille blanche* **10**, special B, 627–635, Sept. 1955.

Data by Dufour on the performance of a long round-pipe sand settler are analyzed. The Schmidt-Rouse equation for rectangular ducts gives too high concentrations at the bottom. A theoretical analysis equating the upward and downward solid transport at each level, employing the Prandtl mixing length L for the length of travel of eddies, and using for the upward and (equal) downward turbulent velocities those obtained from L and the local shear stress, surprisingly yields exactly double the relative (logarithmic) concentration gradient of Schmidt-Rouse, but is still too low. A method of numerical integration of the above (integral) equation is also given.

Author suggests agreement of theory and data may improve by using a distribution of turbulent velocities, rather than a single value, as a function of depth. C. F. Bonilla, USA

3450. Bascher, P., Air filters for ventilating and air conditioning installations, *Sulzer tech. Rev.* **37**, 2, 1–15, 1955.

The amount of fine dust present in conditioned air depends largely on the method of filtration employed, and on the choice of filter design. Equipment and methods used in Sulzer Brothers laboratories are described for measuring the quantity of fine dust present in the air; the ranges of application of the various types

are given. Methods and equipment described are: screen analysis, konimeter, thermal precipitator, the Tyndalliscope, filtering appliances, sedimentation apparatus, dust-collecting plates, condensation nucleus counters. Types of filters described include screen and sieve, viscous-impingement filters, dry filters, bag and hose filters, micro- and ultra-filters, electrostatic precipitators, air washers, centrifugal separators, acid separators. The test rig used for the measurements is described and the efficiency of dust collection is shown in curves.

Of special interest is the very complete spectrum of particle sizes of liquid droplets and solid dust elements ranging from foundry sand and rain drops to smoke and mist particles, giving the type of commercial filters applicable to the different particle sizes. K. J. DeJuhasz, Germany

Geophysics, Meteorology, Oceanography

(See also Revs. 3229, 3303, 3330, 3413)

3451. Murphy, M. J., and Bycroft, G. N., The response of a nonlinear oscillator to an earthquake, *Bull. seism. Soc. Amer.* **46**, 1, 57-65, Jan. 1956.

Seismographic records are analyzed for their frequency spectra by allowing these records to actuate a torsion pendulum of variable resonance frequency [M. A. Biot, title source **31**, p. 151, 1941]. Thus the pendulum is used as a computing device. Authors study the change in the properties of this instrument as a spectral analyzer when a nonlinearity is added to its motion, by introducing additional nonlinear restoring force devices. Motive is to see if naturally present nonlinearities in torsional analyzers alter the form of the spectrum. Since established theory of instrument assumes purely linear properties, nonlinearities might cause false spectra.

This paper is almost entirely experimental. It is found that nonlinearities have marked effect on acceleration spectra, little effect on velocity spectra. No attempt is made at theoretical analysis because the nonlinear term makes the differential equation "intractable" and authors cannot explain the different nature of the results in velocity and acceleration spectra.

A. Leitner, USA

3452. Knopoff, L., The attenuation of compression waves in lossy media, *Bull. seism. Soc. Amer.* **46**, 1, 47-56, Jan. 1956.

Author first evaluates broadening of plane compression pulses in viscoelastic media. This result is combined with a known property of solutions of plane wave equations to show that accelerations due to spherical stress impulses fall off as the 5/2 power of distance at large distances. Ray optics are used to determine a theoretical directivity curve for an ideal transducer attached to a plane slab of viscoelastic material. Experimental verification using a wax slab indicates the excellent directional properties of oil-coupled lithium sulfate transducers. Further observations on multiple reflections verify that wax does have loss properties that can be properly attributed to an internal viscosity.

The transducer properties should be of considerable interest to geophysicists and seismologists. The analysis should interest anyone concerned with damage to subterranean structures resulting from surface blasts. J. H. Huth, USA

3453. Matschinski, M., Integral properties of the flow field and functional examples in fluid flow: solidification of soil and erosion by wind (in French), *C. R. Acad. Sci. Paris* **242**, 13, 1683-1686, Mar. 1956.

Brief note on important application of flow-field theory to erosion of geological formations by wind and sand explains adequately the three- and four-edge patterns developed by exposed surfaces. Theory also explains tendency toward solidification of loose structures, but this aspect is probably surmise.

J. M. DallaValle, USA

3454. Gamburtsev, G. A., and Berzon, I. S., High-frequency seismic prospecting (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **101**, 5, 841-844, 1955 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 7 pp.).

3455. Crane, H. L., and Chilton, R. G., Measurements of atmospheric turbulence over a wide range of wave length for one meteorological condition, *NACA TN* 3702, 18 pp., June 1956.

A power spectrum of gust vertical velocity over a wide range of wave lengths, 10 to 60,000 ft, has been obtained by a simultaneous set of measurements in flight. Method used, which had advantage of not involving airplane transfer functions, proved practicable. Data were obtained on film records, and power spectrum was calculated by digital methods.

From authors' summary by W. A. Baum, USA

3456. Sakagami, J., On the structure of the atmospheric turbulence near the ground. II, *Ochanomizu Univ., Tokyo, Natur. Sci. Rep.* **2**, 62-78, Nov. 1951.

3457. Roy, A. K., Rain-making, its present position and future possibilities, Council of scient. & indust. Research, New Delhi, 17 pp., 9 figs., 1955.

Lubrication; Bearings; Wear

(See also Revs. 3171, 3172, 3252, 3256, 3257)

3458. Philipzik, W., On the hydrodynamic theory of lubrication (in German), *ZAMM* **36**, 1/2, 51-60, Jan./Feb. 1956.

The relaxation method of Gouse and Southwell is used to obtain approximate solutions to Reynolds equations as applied to a partial journal bearing with end leakage. In addition, the axial pressure distribution is examined, and a minimum theorem for bearing friction is proposed.

From author's summary by T. P. Goodman, USA

3459. Barwell, F. T., Grunberg, L., Milne, A. A., and Wright, K. H. R., Applications of some physical methods to lubrication research, Proc. 4th World Petroleum Cong.-Sec. VI/C, Prepr., no. 3, 21 pp., 1955.

A general discussion of past research in contrast to the latest methods in use by the Lubrication Division, Mechanical Research Laboratory, Department of Scientific and Industrial Research, Great Britain.

Results of electron microscope studies to analyze wear processes, scuffing, detergent and used crankcase oils, and greases are presented. Comparison is made with optical microscopy applied to taper sections. A "cross-cylinder" machine developed to study scuffing is discussed. Use of radioactive tracers in wear study is considered in light of the health hazards associated with this method. Measurement of surface topography by stylus, and optical interference method are mentioned, while micrographs of surfaces coated with an evaporated film of aluminum are presented. The running position of a journal in a sleeve bearing and the resulting oil-film thickness are determined by a pneumatic micrometer in which a jet of air is used as the sensing head; this method is a development of the laboratory. Oxide films, their formation and relation to boundary lubrication, are briefly discussed. An apparatus for investigating oxide films is shown diagrammatically and results are presented.

Paper reviews former research techniques and current methods in use at M.E.R.L. The object of the presentation is stated in part by the authors' conclusion: "The indirect nature of the modern tools, the fact that we are working in regions where sight and touch can no longer provide a conceptual background against which the behavior of instruments can be judged, means that we must devote at least as much effort to the study of the characteristics of our instruments as to what they may tell us."

C. J. Vogt, USA

3460. **Sternlicht, B., Experimental verification of theoretical investigations into half-frequency whirl,** ASME-ASLE Lubrication Conf., Indianapolis, Ind. Oct. 1955. Pap. 55-LUB-20, 10 pp. + 17 figs.

The problem of half-frequency whirl of journal bearings is investigated. A theoretical stability analysis is carried out and is checked experimentally for two-bearing applications.

From author's summary by B. A. Boley, USA

3461. **Lee, J. C., Analysis of partial journal bearings under steady loads,** ASME-ASLE Lubrication Conf., Indianapolis, Ind., Oct. 1955. Pap. 55-LUB-1, 11 pp. + 13 figs.

Author analyzes partial journal bearing characteristics with zero end leakage. Two operating conditions are defined. In one, flow is adequate to maintain a positive pressure distribution over the entire bearing arc. In the other, the flow is such that, downstream of the maximum pressure position, the pressure is negative, leading to rupture or cavitation of the film. Aside from the condition that the pressure at film inlet and outlet edges equals atmospheric, Reynolds equation in the latter case must satisfy the additional boundary condition that the pressure gradient at the film exit is zero.

Final results are presented in terms of a composite graph of friction factor, load factor, flow factor, and lubricant film exit angle as functions of eccentricity and inlet film angle. Graph shows that, for eccentricities greater than 0.95, load factor is essentially independent of bearing arc due to pressure concentration within a 30° arc around minimum film thickness position.

Analysis includes application of results to evaluation of starved bearing operation for cavitating flow. In this case the flow factor is independent and the inlet film angle is dependent.

H. E. Brandmaier, USA

3462. **Wilcock, D. F., Predicting performance of starved bearings,** ASME-ASLE Lubrication Conf., Indianapolis, Ind., Oct. 1955. Pap. 55-LUB-9, 9 pp. + 9 figs.

Based on data supplied by author and other investigators, paper presents a procedure for determining performance of starved bearings (wick feed, oil ring feed, single hole feed, etc.). Curves of eccentricity, attitude angle, oil-flow coefficient, and power-loss coefficient as functions of Sommerfeld number and oil-film arc length, which are required for the procedure, are given for a length-to-diameter ratio of 0.5.

Example is presented for a bearing fed by a single oil hole. Comparison with bearing of same dimensions having two axial feed grooves at 90° and 270° shows that starved bearing operates 40% hotter.

Graphical solution is also presented to predict time to failure after oil feed is completely cut off. Reviewer notes that cumbersome graphical differentiation required may be avoided by changing independent variable from eccentricity to oil-flow coefficient.

H. E. Brandmaier, USA

3463. **Izawa, M., A study on the running friction of ball bearing,** *J. sci. Res. Inst. Tokyo* **49,** 310-317, Dec. 1955.

Paper deals with losses in lubricated ball bearings. Experimental measurements of temperature and friction torque are made on 20-mm and 35-mm bore bearings at several loads and speeds with three different oils, drop-fed at 1 to 2 cc/min. Empirical relation is deduced from data relating friction torque to radial load, number and size of balls, radial clearance, ball pocket clearance, oil viscosity, and speed.

Reviewer would hesitate to apply empirical equation to situation much different from that utilized in tests. Neither effect of ratio of ball radius to transverse radius nor oil flow rate has been determined. From practical use standpoint, relation is difficult to apply since equilibrium temperature is unknown.

J. B. Bidwell, USA

Letters to the Editor

3464. Concerning AMR 9, Rev. 1134 (April 1956): **Vagas, I., Proof of model laws for decanting basins** (in Hungarian), the bibliographical heading should be: *Hidrölogiai Közlöny* **35,** 9/10, 327-330, Oct. 1955.

The editors regret this error.

3465. **Re AMR 8, Rev. 2845 (September, 1955): Kramer, J. J., and Stanitz, J. D., Prediction of losses induced by angle of attack in cascades of sharp-nosed blades for incompressible and subsonic compressible flow,** *NACA TN* 3149, 45 pp., Jan. 1955.

The assumption that the resultant force on the blade is normal to the blade direction is made in order to determine the maximum loss incurred across the blade row. This assumption must, of course, differ from the standard potential flow theory because the potential flow is isentropic. If the blade force were assumed to be the same as that for potential flow, the computed loss would be zero.

The assumption that the deviation angle is the same for potential flow as for viscous flow is not made in the report. The deviation angle for potential flow through a cascade of flat plates is introduced only as a sidelight in order to give some idea of the trend and order of magnitude of the effect of the deviation angle for flow of a real fluid.

J. J. Kramer and J. D. Stanitz, USA

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GERARD, G., Minimum weight analysis of compression structures, New York, New York University Press, 1956, xiv + 194 pp. $6.

GIET, A., Abacs or nomograms; an introduction to their theory and construction illustrated by examples from engineering and physics, New York, Philosophical Library, Inc.; London, Iliffe & Sons Ltd., 1956, ix + 225 pp. $12.

GOLDING, E. W., The generation of electricity by wind power, New York, Philosophical Library, Inc., 1956, xvi + 318 pp. $12.

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LALESCU, T., Introducere la Teoria Ecuatiilor Integrale, Bucaresti, Editura Academiei Republicii Populare Romine, 1956, 131 pp. Lei 5.90.

OSTROWSKI, A., Vorlesungen über Differential-und Integralrechnung. Bd. III: Integralrechnung auf dem Gebiete mehrerer Variablen, Basel, Verlag Birkhauser, 1954, 475 pp.

PATRAULEA, N.N., Aerodinamica Suprafetelor Permeabile, Bucaresti, Editura Academiei Republicii Populare Romine, 1956, 173 pp. Lei 7.35.

ROTHBART, H. A., Cams. Design, dynamics, and accuracy, New York, John Wiley & Sons, Inc., 1956, xiv + 350 pp. $9.50.

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TÖLKE, F., Veröffentlichungen zur Erforschung der Drunkstossprobleme in Wasserkraftanlagen und Rohrleitungen, Berlin, Springer-Verlag, 1956, v + 149 pp. DM 37.50.

TRANTER, C. J., Integral transforms in mathematical physics, 2nd ed., New York, John Wiley & Sons, Inc., 1956, ix + 133 pp. $2.

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ZEISE, H., Thermodynamik; auf den Grundlagen der Quantentheorie, Quantenstatistik und Spektroskopie, Bd. III/1 Ergebnisse in tabellarischer und graphischer Form, Tabellen, Leipzig, S. Hirzel Verlag, 1954, xl + 311 pp. DM 20.

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Acosta, A. J. 3344
Adamson, B. 3188
Adler, A. A. 3182
Ainsworth, F. W. 3299
Aitken, A. C. 3154
Anderson, G. F. 3318
Andre, J. 3174
Andreev, N. M. 3429
Andronov, A. A. 3302
Aronofsky, J. S. 3446
Aronovich, G. V. 3302
Aruffo, G. 3153
Ashley, H. 3332
Baron, M. L. 3184
Barrère, M. 3422
Barwell, F. T. . . . 3254, 3459
Bascher, P. 3450
Bazer, J. 3275
Becker, E. 3301
Bendrikov, G. A. 3173
Berio, A. 3247
Berker, R. 3279
Berzon, I. S. 3454
Bevans, J. T. 3412
Bhagavantam, S. 3258
Biot, M. A. 3190, 3191, 3377
Bisplinghoff, R. L. 3332
Blachman, N. M. 3161
Blankenbaker, J. 3164
Blanpain, E. 3259
Boenke, G. 3167
Bogdanoff, J. L. 3189
Bogdonoff, S. M. 3290
Botman, M. 3255
Bouvard, M. 3449
Bowden, D. T. 3406
Bowerman, R. D. 3344
Braun, O. 3196
Braun, W. H. 3313
Broadbent, E. G. 3342
Broglio, L. 3241, 3295
Brunner, W. 3209
Bryant, R. A. A. 3288
Bundy, F. P. 3424
Burian, K. 3177
Busby, J. 3436
Bycroft, G. N. 3451
Cadambe, V. 3242
Camiz, V. 3198
Capey, E. C. 3213
Carmi, A. 3404
Carroll, J. B. 3318
Crane, H. L. 3455
Cronk, A. E. 3323
Czarnecki, K. R. 3401
Cheers, F. 3349
Chenea, P. F. 3252
Chilton, R. G. 3455
Christodoulides, S. P. . . 3200
Clark, L. G. 3217
Clough, R. W. 3229
Coales, J. F. 3175
Colwell, L. V. 3261
Cooke, J. R. 3363
Costilow, E. L. 3345
Cox, H. L. 3214
Dadabaiev, K. B. 3272
Daily, J. W. 3267
Datsev, A. B. . . . 3384, 3385
DeGroff, H. M. 3391
De Groot, S. R. 3378
Demarkles, L. R. 3223
Dengler, M. A. 3187
Diederich, F. W. 3321
Dittrich, R. T. 3348
Donoughe, P. L. 3398
Dropkin, D. 3404
Drucker, D. C. 3243
Dryden, H. L. 3311
Dumas, R. 3315
Dunkle, R. V. 3412
Durfee, W. H. 3402
Eckhaus, W. 3298, 3334
Ehrich, F. F. 3266
Einstein, A. 3372
Eisenmann, J. 3227
Emmons, H. W. 3419
Erickson, A. J. 3421
Etinberg, I. E. 3347
Fales, E. N. 3316
Farinha, J. S. B. 3232
Favre, A. 3315
Feldtkeller, R. 3431
Fieller, E. C. 3157
Finkelstein, A. B. 3396
Fischer, F. A. 3426
Foa, J. V. 3324
Foëx, M. 3411
Fourier, J. 3383
Fowler, F., Jr. 3165
Fraenkel, L. E. 3283
Franciosi, V. 3233
Franssila, M. 3413
Frederick, C. L. 3361
Fritzsche, A. F. 3397
Gadd, G. E. 3296
Gail, A. 3324
Galbiati, A. 3409
Gamburtsev, G. A. 3454
Gaukroger, D. R. 3335
Gaviglio, J. 3315
Geckler, R. D. 3192
Geller, E. W. 3360
Gessow, A. 3340
Gibson, J. E. 3176
Giddings, J. C. 3415
Glinkov, M. A. 3425
Gol'denblat, I. V. 3249
Goodman, T. R. 3324
Gratsyanskiĭ, M. N. . . . 3271
Graves, C. C. 3348
Grigor'ev, A. S. 3246
Grogan, G. C. 3277
Gross, R. A. 3417
Grunberg, L. 3459
Hahn, R. S. 3260
Halfman, R. L. 3332
Hall, M. G. 3280
Hall, W. A. 3445
Hamilton, J. A. 3330
Hammitt, A. G. 3290
Harboe, H. 3205
Hartshorn, A. S. 3403
Hedgepeth, J. M. 3337
Helberg, H. W. 3434
Herning, F. 3352
Heyson, H. H. 3325
Hill, N. E. 3376
Hinze, J. O. 3278
Hirschfelder, J. O. 3415
Hoeland, G. 3207
Holt, Maurice 3289
Holzweissig, F. 3186
Hool, J. N. 3307, 3308
Hopkins, E. J. 3350
Horne, M. R. 3246
Howard, L. N. 3293
Howe, D. 3239
Hsu, E. Y. 3317
Hui, E. 3218
Hunt, J. N. 3303
Huppert, M. C. 3345
Inomata, S. 3170
Islitzer, N. F. 3413
Izawa, M. 3463
Jablecki, L. S. 3231
Jenkins, D. E. 3225
Johnson, F. V. 3371
Johnson, J. B. 3362
Johnson, R. C. 3355
Johnson, R. L. 3172
Johnson, V. E., Jr. 3267
Jones, A. L. 3323
Junger, M. C. 3437
Kaczkowski, Z. 3210
Kani, G. 3235
Kapadnis, D. G. 3405
Karadzhi, K. M. 3274
Karp, S. N. 3275
Kartvelishvili, N. A. . . . 3273
Khavkin, L. P. 3356
King, J. W. H. 3225
Kirby, D. A. 3369
Klein, B. . . 3214, 3220, 3427
Kliever, W. H. 3262, 3263, 3264
Knopoff, L. 3452
Kogan, A. 3294
Koiter, W. T. 3230
Kopal, Z. 3410
Kosara, J. 3215
Kozlov, B. K. 3358
Krishnan, S. 3242
Kuhlmann, A. 3423
Kurz, P. F. 3171
Kusukawa, K.-I. . . 3285, 3286

(Continued on inside back cover)

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE (*Continued*)

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Lakshmana Rao, S. K. . . 3185
Lamb, O. P. 3323
Lawley, L. E. 3438
Leathers, J. W. 3369
Lee, J. C. 3461
Lees, L. 3390
Lefkovits, H. C. 3268
Leidenfrost, W. 3380
Leifer, M. 3161
Leist, K. 3351
Leonard, R. W. 3337
Lerner, I. S. 3159
Lewis, T. 3157
Licher, R. M. 3292
Liebmann, G. 3386
Linahan, T. C. 3407
Lippert, W. K. R. 3430
Little, G. 3226
Livingood, J. N. B. 3398
Ljunggren, K. 3382
Lotsianskiĭ, L. G. 3306
Lyon, R. H. 3432
Marble, F. E. 3418
Marguerre, K. 3179
Markey, M. F. 3300
Martinek, J. 3183, 3276
Matschinski, M. 3453
Matthews, C. S. 3268
Matthews, D. L. 3293
Mawardi, O. K. 3439
McMaster, S. 3177
Michner, M. 3417
Miesse, C. C. 3420
Miles, J. W. 3180
Miller, A. P. 3392
Miller, E. E. 3444
Miller, R. D. 3444
Milne, A. A. 3459
Milne, R. D. 3338
Miner, D. F. 3257
Mink, K. 3201
Mironov, S. A. 3238
Moore, F. K. 3341
Morgan, V. A. 3234
Moulton, R. W. 3392
Moutet, H. 3422
Mukhlenov, I. P. . 3399, 3400
Muncey, R. W. 3388
Murphy, C. H. 3322
Murphy, M. J. 3451
Murty, Y. K. 3258
Muttnyánszky, Á. 3166
Nelson, E. 3160
Nerge, G. 3168
Nethaway, J. E. 3364
Netrebko, V. P. 3199
Nicholson, L. F. 3403
Nikitin, Ya. A. 3237
Niskanen, E. 3222
Noe, J. D. 3158
Olsson, C. O. 3333
Oravas, G. 3203, 3211
Orlik-Rückemann, K. . . 3333
Ormerod, A. O. 3414
Owe Berg, T. G. 3379
Owen, P. R. 3414
Paoli, R. 3251
Paynter, H. M. 3408
Pearson, E. S. 3157
Perkins, F. M. 3442
Peschka, W. 3346
Peszkowski, S. 3265
Petersen, N. V. 3441
Peterson, M. B. 3172
Pfleiderer, C. 3343
Philipzik, W. 3458
Phillips, O. M. 3314
Pode, L. 3155
Poggi, L. 3357
Porter, J. D. 3446
Puttock, D. R. . . . 3327, 3328
Rainey, A. G. 3339
Ramachandra, S. M. . . . 3326
Ramsey, N. F. 3373
Rannie, W. D. 3389
Rheinboldt, W. 3305
Richardson, E. G. 3436
Rivlin, R. S. 3195
Reed, R. D. C. 3438
Reid, W. P. 3443
Reid, W. H. 3312
Roach, A. E. 3252
Robey, D. H. 3433
Robinson, A. 3448
Rodger, O. E. 3193
Rogers, D. E. 3418
Rongved, L. 3197
Rosenthal, L. 3155
Rössner, W. 3169
Rowe, R. E. 3226
Roy, A. K. 3457
Rozenblum, V. I. 3245
Rüdiger, D. 3212
Sagomonian, A. Ya. . . . 3297
Sakagami, J. 3456
Sanders, J. L., Jr. 3240
Sanger-Bredt, I. 3416
Sanyal, L. 3309
Sarjant, R. J. 3387
Saxena, S. C. 3374, 3375
Schenker, L. 3228
Schimanek, E. 3381
Schindler, K. 3206
Schneider, P. J. 3394
Scott, N. R. 3162, 3163
Seastone, J. B. 3257
Sechler, E. E. 3221
Seibert, P. 3174
Shapiro, A. H. 3421
Shestopalov, V. P. 3310
Shields, R. T. 3329
Shuleshko, P. 3216
Sibulkin, M. 3393
Sievers, H. 3236
Sinclair, A. R. 3401
Sissingh, G. J. 3178
Slack, M. R. 3387
Sleicher, C. A., Jr. . . . 3395
Smolyaninov, N. T. 3270
Sorensen, N. E. 3350
Spence, A. 3369
Spreiter, J. R. 3287
Springer, A. M 3440
Squire, H. B. 3304
Srivastava, B. N. 3375
Stein, M. 3240
Stephenson, J. 3329
Sternlicht, B. 3460
Strella, S. 3253
Strong, H. M. 3424
Suomi, V. E. 3413
Tabor, D. 3256
Takahashi, Y. 3408
Tapscott, R. J. 3340
Tarapov, I. E. 3282
Teodorchik, K. F. 3173
Thibessard, G. 3353
Thompson, A. S. 3193
Thomson, T. A. . . . 3368, 3370
Tietjens, O. 3365
Todd, D. K. 3447
Tribus, M. 3395
Trombe, F. 3411
Tsien, S. H. 3291
Tumarkina, E. S. 3399, 3400
Tyabin, N. V. 3250
Utting, I. E. 3329
Vandrey, F. 3366, 3367
Vannutelli, R. 3331
Venkatasubramanian, V. S. 3435
Vernotte, P. 3152
Verschaffelt, J. E. 3281
Vlieger, J. 3378
Volterra, E. 3194
Vreedenburgh, C. G. J. 3224
Wahl, A. M. 3244
Weidenhammer, F. 3181
Weissinger, J. . . . 3319, 3320
Westphal, W. 3428
Wieghardt, K. 3366
Wilcock, D. F. 3462
Wildhaber, E. 3156
Woinowsky-Krieger, S. 3208
Wood, R. M. 3322
Woodcock, D. L. 3336
Woods, L. C. 3284
Worch, G. 3203
Wright, K. H. R. 3459
Wuest, W. 3354
Yagodin, N. N. 3269
Yeh, G. C. K. . . . 3183, 3276
Yuan, S. W. 3396
Zaytzeff, S. 3204
Zen'kovskiĭ, A. G. 3425
Zlotnick, M. 3321
Zorn, H. C. 3276, 3359
Zuk, W. 3219
Zwicker, E. 3431